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Hydrologic and geochemical controls on metals partitioning in the vadose zone and shallow ground water zone of a highly-contaminated floodplain near Butte Montana

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Hydrologic and geochemical controls on metals partitioning in the vadose zone and shallow ground water zone of a highly-contaminated floodplain near Butte, Montana.

by

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ABSTRACT

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Geology

Hydrologic and geochemical controls on metals partitioning in the vadose zone and shallow ground water zone of a highly-contaminated floodplain near Butte, Montana.

Director: Johnnie N. Moore

The geochemical character of the vadose zone and shallow ground water zone of a small floodplain highly contaminated with mining wastes was determined. Heavy metals are partitioned into water soluble, reducible, oxidizable, and residual phases (solid phases), and into aqueous phase. Vadose zone pore water pH decreases from 4 near the surface to 2.5 immediately above the water table. Dissolved metal concentrations in the vadose zone (Fe = 0.5-3600 ppm, Zn = 44-2500 ppm, Mn = 15-1500 ppm, Cu = 12-1800 ppm) are controlled by pH, dilution by infiltrating water, and sediment resistance to desorb metals. Metal concentrations in the sediment are highly variable because of heterogeneous floodplain stratigraphy. Total sediment metal concentrations generally decrease with depth to approximately 40 - 60 cm, then become less variable down to the water table. At the water table, reducible and oxidizable metal concentrations increase by as much as 50 percent. This profile suggests that 1) metals are being concentrated in surface sediment by evaporation of soil water at the surface, and 2) metals precipitate at the vadose/ground water interface where water chemistry becomes more reducing and pH increases. Efflorescent surface crusts which form during dry periods are extremely high in water soluble metals (6 wt.% Fe, 3 wt.% Ca, 1.6 wt.% Zn, 0.4 wt.% Cu, and 85 μg Cd per g sediment). Metal concentrations in fine-grained, organic-rich tailings layers are 2-3 times those in coarse-grained tailings, and 10-50 times those in the pre-mining floodplain. Sediment mineralogy, lithology and stratigraphy are important in partitioning metals. Individual metals characteristically partition into certain fractions, suggesting that Zn, Cd, and Pb sulfides are still abundant in the tailings, but that Cu has been somewhat oxidized out of sulfide minerals into oxidized coatings. This research shows that metals partitioning in the shallow vadose zone is highly dependent on infiltration and subsequent upward movement of soil water and on sediment lithology, whereas in the deeper vadose zone and water table zone, water pH and Eh are the major factors influencing metals partitioning.

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I dedicate this thesis to my parents, John Patrick and Rita Lee Lucy.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Mining at Butte, Montana, over the past 100 years has disturbed well over 300 million m^3 of rock (Moore and Luoma, 1990). Mine tailings were discarded in tailings ponds in Butte, or along Silver Bow Creek. Floods in the early part of this century, including the large flood of 1908 transported the tailings downstream and deposited them in the floodplains of Silver Bow Creek and the upper Clark Fork River (Titan Env. Corp., 1995) where metal-sulfide minerals in the tailings are weathering and oxidizing at an accelerated rate. Oxidation releases acid and metals into vadose zone pore water and ground water. Because high concentrations of metals such as Cd, Cu, As, and Zn, can be toxic to aquatic and terrestrial life, including humans, a large portion of the area around and downstream from Butte has been designated as a Superfund site (Moore and Luoma, 1990).

Dissolved metals from the oxidation of sulfide minerals is the major input of contaminants into the environment at the Silver Bow Creek study site. Sulfide oxidation has been intensively studied, and good descriptions are given by Nordstrom (1982), and Nicholson (1994). Basically, acidic, metal-rich water is produced when oxygenated water comes in contact with sulfide minerals in the tailings. The sulfides oxidize, releasing sulfate and metal ions into the water. Pyrite oxidation is commonly used in discussions of acid mine drainage (Ritchie, 1994: Alpers et al., 1994: Blowes and Jambor, 1990: Bigham et al., 1990) because it is a common mineral found in sulfidic mine tailings and considerable laboratory work has been done to characterize pyrite oxidation. The overall process describing pyrite oxidation is given by:

$$FeS_{2(s)} + (15/4)O_{2(aq)} + (7/2)H_2O_{(l)} \rightarrow Fe(OH)_{3(s)} + 2H_2SO_{4(aq)} \quad [1]$$

in which pyrite and water, in the presence of oxygen, form sparingly soluble ferric hydroxide and sulfuric acid (Nordstrom, 1982). This reaction is probably composed of a set of simpler reactions:

$$FeS_{2(s)} + O_2 + 2H^+ \rightarrow Fe^{2+} + S_2^0 + H_2O_2 \quad [2]$$

$$Fe^{2+} + (5/2)H_2O + 1/4O_2 \rightarrow Fe(OH)_{3(s)} + 2H^+ \quad [3]$$

$$S_2^0 + 3O_2 + 2H_2O \rightarrow 2SO_4^{2-} + 4H^+ \quad [4]$$

Reaction 2 describes the initial oxidation of pyrite. Reaction 4 describes the oxidation of the sulfur produced in reaction 2. It is also the initial acid producing reaction. The ferrous iron produced in reaction 2 may be oxidized to ferric iron which is sparingly soluble above a pH of about 3 and precipitates as ferrihydrite (reaction 3). At pH < 3, iron-oxidizing bacteria thrive and catalyze the oxidation of Fe^{2+} to Fe^{3+} (Bigham *et al.*, 1990; Gould *et al.* 1994). At low pH, ferric iron is more soluble and becomes an important oxidizing agent on pyrite according to the reaction:

$$14Fe^{3+} + FeS_{2(s)} + 8H_2O \rightarrow 15Fe^{2+} + 2SO_4^{2-} + 16H^+ \quad [5]$$

Free oxygen is not required for this reaction to proceed (Nordstrom, 1982).

Nimick and Moore (1991) point out that the tailings in the Butte system contain many other sulfides (Table 1) which may not react to weathering in the same manner as pyrite does. Nordstrom (1982) states that a mixture of sulfides such as chalcopyrite and sphalerite with pyrite creates a more acidic, metal-rich solution while decreasing the oxidation rate of the pyrite itself.

Interaction of acidic, metal-rich vadose zone water and ground water with Silver Bow Creek floodplain sediments and stream water determines where metals are partitioned. Understanding the processes governing metal partitioning in mining-contaminated environments is essential to implementing successful remediation programs. Without knowledge of where metals are partitioned, and a clear understanding of the factors controlling their partitioning, remedial strategies may not address the whole problem or may just postpone metal contamination in the environment. The vadose zone of the Silver Bow Creek floodplain may be very important in mobilizing and/or immobilizing metals in the Clark Fork System. Tailings in the vadose zone are in a relatively unstable environment as compared to a sulfide ore body, deep ground water aquifers, or deep tailings impoundments. Components effecting the vadose zone may include microbial processes, surface processes such as erosion and infiltration, and deeper processes such as reactions at the water table. Most previous work involving vadose zones in metal-contaminated environments has been done in tailings impoundments (Al *et al.*, 1994; Appleyard and Blowes, 1994; Blowes and Jambor, 1990; Blowes *et al.*, 1991; Blowes *et al.*, 1992; Robertson, 1994). They have shown that infiltration, carbonate buffering capacity, original tailings mineralogy, presence of hardpan layers, and time are important factors (Blowes and Jambor, 1990; Al, *et al.*, 1994; Blowes, *et al.*, 1992). Others have shown that organic matter plays an important role in partitioning of metals in soils (Elliott, *et al.*, 1986; Levy, *et al.*, 1992). With the exception of remediation investigations in the Clark Fork Superfund site (Titan Env. Corp., 1995; CH2M Hill, 1987; Brooks, 1988) the vadose zone of mining-impacted floodplains has not been

examined. This study examines a floodplain downstream from Butte, Montana where mine tailings are present throughout the vadose zone and in direct contact with ground water and stream water.

The study site is located approximately 15 km west of Butte, Montana in the floodplain of Silver Bow Creek in the Upper Clark Fork River drainage (Fig. 1 and Fig. 2). The geology and hydrology of the site was determined in a previous study (Smart, 1995; Benner, 1994). Silver Bow Creek is a perennial stream with discharge of 20-50 cfs (Titan Env. Corp., 1995). Discharge measured at the site on several occasions ranged from 30-56 cfs and averaged about 44 cfs (Smart, 1995). Discharge is generally higher during spring run-off and during and immediately after a thunderstorm event in the area. Cyclical daily fluctuations in discharge result from increased discharge from the Butte sewage treatment plant and a pipeline upstream from the site. At a depth of about 4-6 m, the shallow unconfined aquifer is bounded by a clay-rich layer interpreted to be weathered volcanic bedrock (Titan Env. Corp., 1995) (Fig. 3). Overlying the clay is the pre-mining floodplain composed of sand, gravel, and cobbles. Tailings and are draped on the pre-mining floodplain and range from 0 to 1.75 meters thick at the site. The water table is quite shallow and averages about one to two meters below the surface. Therefore, tailings reside in both the vadose zone and the shallow ground water zone over much of the floodplain. Hydraulic conductivity of the aquifer ranges from 14-166 ft/day (Smart, 1995). Ground water flow is to the west, down the alluvial valley (Fig. 2). Locally, ground water flows into the stream through the up-gradient bank where the stream cuts across the valley, perpendicular to ground water flow (Smart, 1995; Benner

et al. 1995). Similarly, stream water flows into the ground through the down-gradient bank and the base of the stream. This relationship between stream and ground water are the basis of the transition zone described by Benner *et al.* (1995). The surface water and ground water at the site are well connected (Smart, 1995; Benner *et al.* 1995). Stream level changes are mimicked by ground water. Water table fluctuations (about 1.5 cm daily fluctuation) measured three meters away from the stream are about one half the magnitude of the stream level changes (2.5 - 3.0 cm daily) (Fig. 4). There are zones of highly contaminated ground water (pH 4, dissolved metal concentrations of 7 ppm Cu, 20 ppm Mn, 20 ppm Zn, 700 ppm SO_4), and zones of less contaminated ground water (pH 6.5, and 0.2 ppm Cu, 2 ppm Mn, 3 ppm Zn, 1200 ppm SO_4). Commonly, the floodplain sediments are coated with red oxyhydroxide coatings. At the water table, a ferricrete layer or "hardpan" is commonly found in which the coatings cement grains.

The area around Butte receives an average of 31 cm of precipitation per year (141 cm snow/yr.) (National Weather Service, 1996) which is available to the floodplain tailings mostly as spring runoff and summer rainstorms. The infrequency of rainfall and warm temperatures in the summer months allow the surface of the floodplain to dry out. Efflorescent surface crusts like those found downstream and on other mining-impacted floodplains form during dry periods (Nimick and Moore, 1991).

Objectives of this study were to 1) characterize the water and sediment in the vadose zone and shallow ground water zone, 2) quantify spatial and temporal geochemical and hydrologic trends, and 3) identify geochemical and hydrologic controls on the partitioning of metals between the aqueous and solid phases. The information gathered

in this study shows that metals partitioning in the shallow vadose zone is highly dependent on a cycle of infiltration of precipitation and later upward movement of soil water. In the deeper portions of the vadose zone, interaction between sediment and ground water is the dominant control.

METHODS

In order to study a complete representation of the geochemical and hydrologic environment at the research site, water and sediment samples were collected from the vadose zone, shallow ground water zone, and stream. To quantify the relationship between vadose zone and ground water contamination, two sites were selected for intensive study (i.e. pore water, ground water, soil water, and sediment were examined) (Fig. 2). Site A was selected because previous work revealed the ground water contained relatively low concentrations of metals (Benner, 1994). Site B was selected because the ground water contained very high concentrations of metals (Benner, 1994). Additional ground water, surface water, and sediment were sampled at a variety of other locations on the floodplain to quantify site-wide geochemistry (Appendix of Photographs and Detailed Site Maps).

Water

Pore water samples were collected approximately every two weeks using suction lysimeters (pressure-vacuum lysimeter of Fetter, 1993). Each lysimeter was constructed of a five cm porous ceramic cup glued with epoxy to five cm PVC pipe and plugged on the top with a large rubber stopper. Two pieces of Tygon tubing penetrated the stopper:

one to allow pressurizing and suction; and one to allow extraction of the water in the cup. The lysimeters were installed by hand augering a hole to the desired depth, filling the bottom of the hole with a silica flour slurry (to ensure proper interaction of the cup with the sediment) and immediately inserting the lysimeter. The hole was then back-filled with a 10-15 cm bentonite plug, back-filled with augered sediment, and sealed with a five cm bentonite seal. The lysimeter was placed under a vacuum of approximately negative 60 centibars (cb) pressure until sample extraction (a few hours to two weeks). To extract the accumulated sample water, nitrogen gas (to minimize contact with atmospheric oxygen) was used to pressurize the lysimeter and force the sample in the cup of the lysimeter up the tube, through an attached 0.45 μm membrane Gelman GN-6 filter and into a 500 ml plastic sample bottle. Field measurements (pH, temperature, and dissolved oxygen by Orion electrodes) were measured and samples for cation and anion analysis were collected. Cation samples were acidified with concentrated trace-metal grade nitric acid to approximately pH 2.

Ground water was sampled via piezometers constructed of 3.2 cm PVC pipe with the bottom six inches slotted. To remove stagnant water in the piezometer, one and one-half well volumes were peristoltically pumped and discarded before sampling. Field parameters were measured in a flow-through sampling apparatus to minimize contact with the atmosphere. The ground water was pumped into a 200 ml plastic reservoir through an inflow tube attached to the peristaltic pump. The pH/temperature and dissolved oxygen electrodes were inserted through a rubber stopper into the enclosed reservoir. A constant flow of water through the sampling apparatus was maintained

while field parameters were measured. Cation and anion samples were pumped through an in-line 0.45μm membrane Gelman GN-6 filter into 500 ml plastic sample bottles. Cation samples were acidified with concentrated trace-metal grade nitric acid to approximately pH 2. Stream water was pumped from the middle of the stream into the sample apparatus or sample bottles and treated in the same manner as ground water. All water samples were transported to the laboratory on ice and refrigerated until analysis. Water samples were analyzed at the Geology Analytical Laboratory, University of Montana within two weeks for Al, As, Ca, Cd, Co, Cu, Fe, Mg, Mn, Mo, Na, Ni, Pb, Si, Sr, Ti, Zn using a Jarrell Ash inductively coupled plasma emission spectophotometer (ICP). Sulfate concentrations were determined within one week of collection using a DIONEX 2000 ion chromatograph (IC). Samples were not routinely analyzed for other anions because the extremely high sulfate concentrations were orders of magnitude greater than other anion concentrations.

Quality assurance/quality control measures for aqueous analysis included field blanks and duplicates, and laboratory blanks, standards, and duplicates (Table 2). Field blanks were below instrument detection limit (BIDL). Twenty percent of laboratory blanks exceeded detection limits in one to five elements (Table 2); however, blanks with exceedences were analyzed along with samples of highly contaminated waters and sediment extractions. Instrument carry-over from high concentration samples to the analysis of the blanks appeared as detectable amounts of some elements. When the blanks were analyzed prior to analyzing high concentration samples, concentrations were below instrument detection limits. The error introduced to high concentration samples

from instrument carry-over is approximately 0.1 ppm. This error is insignificant when compared to sample concentrations. Blanks analyzed with less contaminated water samples never exceeded detection limits. Field and laboratory duplicates were generally within ±11% difference. Exceptions to this occurred when the concentrations were near detection limits. Accuracy was determined by spike addition and comparison to internal, USGS, and EPA standards (Table 2). Spike recoveries were mostly within 85 - 115%. Comparison with external standards (USGS and EPA water standards) were within ±27% of the certified value. The concentrations of elements in these standards are much lower than most of the sample concentrations, so accuracy of the ICP at low concentrations affects only samples with similarly low concentrations (i.e. stream water and uncontaminated ground water). Comparison with internal standards mixed at concentrations comparable to sample concentrations indicates much better accuracy, generally < 9% difference from the prepared concentration.

On several occasions, two samples per day were collected from the suction lysimeters. This was done to assure that representative vadose zone pore water samples were obtained. Analytical values on the first sample, which had been in the lysimeter cup for 4-14 days, were within 10% of the second, 4-5 hr old sample.

Sediment

Sediment samples were obtained from sediment cores pulled from seven locations on the floodplain (Fig. 2). Cores F and G were located in the stream bed and on a gravel bar within the stream, respectively. All others were taken on the floodplain through the vadose zone and into the underlying ground water zone. A generator powered

"Handyman" jackhammer was used to pound a five cm diameter clear, polycarbonate tube down into the sediment as far as possible (usually about 40-50 cm) (Appendix of Photographs and Detailed Site Maps). This core was pulled out of the ground by wrapping a chain around the tube and jacking it out with a heavy-duty bumper jack. The same hole was used to pound another section of tube down as far as possible. In the stream and on the gravel bar, the tubes were pounded down manually using a post pounder.

Upon removal from the ground, the cores were visually inspected and then pushed out of the tube onto a clean plastic ground cloth to be measured and described. Cores were subdivided into stratigraphically defined samples. Each sample was placed into a plastic bag and then iced for transport back to the laboratory. Immediately upon returning to the laboratory, sediment samples were divided into halves. One half was left in the plastic bag and frozen. The other half was placed into an acid washed petri dish and then frozen. After one to three days in the freezer, the samples were transferred to a freeze drier where they were left until completely dry (maximum of five days). This was done to minimize geochemical or microbiological changes which might occur at room temperature or in an oven.

One half of the freeze dried sample was ground to approximately clay size using a Shatter-Box grinder. A set of four sequential extractions similar to those used by Brook (1988) was performed on each of the ground samples. These extractions are designed to remove, sequentially from a sediment sample, the water soluble, reducible, oxidizable, and residual fractions of the sediment. Briefly, the reagents used and the targeted mineral phases are:

1. *Water extraction*: Reagent: water. Phases: water soluble minerals and precipitates formed during freeze drying.
2. *Reducible extraction*: Reagent: 0.25 M hydroxylamine hydrochloride in 25% acetic acid. Phases: oxyhydroxide coatings, oxide minerals, carbonate minerals.
3. *Oxidizable extraction*: Reagent: potassium chlorate and hydrochloric acid. Phases: sulfide minerals, organic matter.
4. *Residual extraction*: Reagent: aqua regia (1:3 HNO_3 to HCl) and hydrofluoric acid, neutralized after extraction with boric acid. Phases: all residual, rock forming minerals such as mafic minerals, and quartz.

See Appendix of Methods for complete description of extraction methods.

The extractions were analyzed for Al, As, Ca, Cd, Co, Cu, Fe, Mg, Mn, Mo, Na, Ni, Pb, Si, Sr, Ti, and Zn using ICP.

As a precision check on the sequential extractions, a total sediment digest was done by subjecting a complete, ground sediment sample to the residual extraction step. The sum of each element recovered in the sequential extractions should equal the amount of that element recovered by the total digest. Sum of sequential extracts was usually within ±12% of the concentration in the total digest (Table 2). However, a significant percentage of the comparisons exceeded ±12% difference. The exceedences are likely due to low concentrations in the extracts which are more difficult to analyze accurately on ICP when other element concentrations are high and/or heterogeneity in the sediment sample.

Reagent blanks carried through the extractions were found to contain significant amounts of impurities, especially Si and Ca (approximately 10 ppm Si and 2 ppm Ca in extract solutions). Residual extracts and total digests had the most impurities because reagent grade boric acid was used to neutralize the hydrofluoric acid. An average concentration of several of these blanks was subtracted from each extract to "blank-correct" final values.

As a quality assurance measure, NIST Sediment Standards were subjected to the extractions. Percent recovery of all elements with certified values reported was generally between 90 and 110 % (Table 2). However, less accuracy is reported for As, Cu, Ni, Si, Sr, and Ti probably because the extraction procedures used were different than those used to obtain certified values, or because of elemental interferences on the ICP (e.g. Fe and Al interference on the As signal). Total sediment metal concentrations for these elements should be interpreted as approximate concentrations.

Replicates (extractions and digestions done on another 0.2 - 0.5 g ground sediment from the same sample) were done to quantify precision of sediment chemistry methods. Concentrations in the replicates were mostly within ±12% of each other for most samples on Al, Ca, Cu, Fe, Mg, Mn, Sr, Zn (Table 2). However, a significant percentage of replicates had > ±12% precision. This is largely because samples were taken from a very heterogeneous floodplain environment with heterogeneous mineralogy, and because concentrations of these elements were below or very near detection limits in some of the extracts. Silicon precision is poor most likely because reagent grade boric acid used to neutralize the hydrofluoric acid in residual and total digestions contained considerable

impurities of Si. It was not possible to obtain representative replicate cores because of heterogeneity of the floodplain.

Each sediment, sample except those from Core E, was analyzed for total carbon and some for inorganic carbon using a UIC CO_2 coulometer. All samples contained <0.03% inorganic carbon by weight. A calcium carbonate standard was run to ensure accuracy. All standards were within ± 5%. Sample replicates were within ±10% of each other (Table 2).

Soil water

Relative soil water was measured with tensiometers placed at various depths through the vadose zone at Sites A and B. Tensiometers measure the negative pressure (suction) imparted to a column of fluid in the instrument by the matrix potential of the soil water. When the soil is drier and the soil water is held more tightly to the soil particles, the instrument will read a more negative pressure. Fine-grained sediment generally has a higher water content than coarse-grained sediment (Merry and Palmer, 1985), so the actual tension registering on the tensiometer's gauge may reflect a very local moisture content (i.e. soil water within a stratigraphic layer). This value may not be directly comparable to values measured by another tensiometer placed in a different lithologic unit. However, the relative change of a single tensiometer may be compared to the relative change of other tensiometers. Tensiometers were installed according to Fetter (1993). Small diameter (2.5 cm) holes were augered to the desired depth and the tensiometer was immediately placed down into the hole. The hole was back-filled with sediment and five cm of bentonite to form a surface seal. The tensiometer was filled

with a 1:1 mixture of antifreeze and water. Readings on all tensiometers were taken at the beginning and ending of each sample day by reading a vacuum gauge attached to the tensiometer. Each time the tensiometer was read it was reset by refilling the solution in the instrument with solution from a reservoir on the tensiometer. Accuracy and precision of tensiometers were not measured in this study, but they have been used successfully in numerous studies (Merry and Palmer, 1986; Ripp and Villaume, 1986; McMahon and Dennehy, 1986).

RESULTS

Partitioning of Metals in the Sediment

The floodplain sediment is very heterogeneous (see photographs in Appendix of Photographs and Detailed Site Maps). Zero to 1.75 m of tailings overlie pre-mining floodplain sediments (Fig. 3). Where the pre-mining sediment could be sampled (by augering or coring) it was gray silty sand. In other places, the pre-mining floodplain could not be sampled by these methods because it consisted of gravel and cobbles. The overlying tailings are mostly medium- to poorly-sorted silty sand, with layers of sand, sandy gravel, pebbly gravel, and silty clay containing varying amounts of organic matter. The organic-rich layers had twigs and small plant remains in them, indicating they may be former root zones or areas of vegetation. All tailings were coated with orange-red to orange-brown amorphous material except in some small sandy layers or on the interior of clay chunks/layers. This "orange" material encrusted sediment at the water table in two of the cores. The coatings match descriptions of lepidocrocite (bright orange),

ferrihydrite (rusty, reddish brown), and goethite (yellowish brown) (Bigham, 1994). These minerals were identified in the vadose zone of a tailings impoundment (Blowes and Jambor, 1990). Jarosite and goethite were reported in "hardpans" or ferricrete (Blowes and Jambor, 1990; Blowes *et al.*, 1991). Ferrihydrite was found to precipitate when acidic ground water and stream water of a contaminated floodplain mixed (Filipek *et al.*, 1987). The coatings are probably composed of a mixture of these minerals along with other metal oxyhydroxides and oxyhydroxysulfates. The upper 40 cm of the vadose zone is generally finer-grained than underlying sandy and gravelly tailings. Several clay layers were observed near the surface. Over most of the floodplain there is a surface clayey layer averaging 4-6 centimeters thick. This layer is light brown in color and becomes very slick when wetter by even a small amount of precipitation (e.g. 0.5 cm). However, even with a moderate rain shower (e.g. 1.5 cm), the sediment beneath the very surface remains dry. Complete sediment core logs and tables of sediment geochemistry data are given in Appendix of Sediment Geochemistry Data.

Sediment geochemistry data reveal the heterogeneity of this floodplain. Much less-contaminated sediment samples from the bottoms of Cores A and D and top of Core C are represented by low concentrations of all elements in all fractions (Fig. 5 and Core A, Fig. 6). The metal-rich sediments are 1.75 m and 0.46 m and thick in Cores A and D, respectively, 60 m from one another. Core C is located on a lower terrace near the stream. The low concentrations of zinc in the upper 46 cm of Core C is typical of other metals, Mn, Cu, Cd (Fig. 5 and Appendix of Sediment Geochemistry Data). Heterogeneity is further demonstrated by the extremely high reducible copper concentrations in the upper

60 cm of Core D as compared to other cores (about 10 x higher in Core D) (Cu in Fig. 5 vs. Fig. 6). Copper is typical of the other metals, Zn = 6x, Mn = 10x, Pb = 10x.

There is a strong general trend in cores located up on the highest level portion of the floodplain (Cores A, B, and E). These cores all show a strong decrease in metal content with depth to the water table (Fig. 6). The uppermost 40 cm of these cores are much higher in total metal content than the underlying vadose zone (Fig. 6). Additionally, metals in water soluble phases are mostly present only in the upper 40 cm. The vadose zone between approximately 40 cm and the water table is lower and relatively constant in total metal content. Core logs show samples from these depths to be visually similar in grain size and color (Fig. 6 and Appendix of Sediment Geochemistry Data).

Zinc and Mn showed marked increase in reducible phase at the depth of the water table in the two floodplain cores in which a ferricrete layer was observed (Cores A and E, Fig. 6). Also, iron in the reducible phase is approximately 30 - 50 % higher in samples at the water table than in samples above or below the water table (Fig. 6). Copper increases in both reducible and oxidizable phases at the water table.

Inorganic carbon in sediment was measured for a few samples and found to be less than 0.03% by weight. Also, original floodplain materials do not contain large amounts of carbonate minerals (the main inorganic carbon source), and the highly-acidic nature of the floodplain sediments has probably caused dissolution of all carbonate minerals that were originally present, so it is assumed that all measured carbon is present as organic carbon. Samples high in organic carbon coincide with finer-grained sediments, and show the highest <u>total</u> metal concentrations (Cu and C in Core A, Pb and C in Core B, Fig. 6).

If metals in these samples are present primarily in sulfide minerals or bound to organic matter, the oxidizable step of the sequential extractions should dissolve them, and thus metals in the oxidizable phase should be higher than metals in other phases. Unfortunately, no distinct correlation between the oxidizable portion of sediment and organic carbon content or grain size is apparent. Instead, the high C/finer-grained samples were simply higher in all phases.

Partitioning of individual metals is consistent in all cores. The highest concentrations of zinc are always in the oxidizable fraction, even in samples with little organic carbon in them (Fig. 5 and Fig. 6). Cadmium and lead usually follow zinc in their partitioning behavior although sediment metal concentration data for Cd and Pb are more variable. The reducible phase of copper is usually the most of the four fractions (Fig. 5 and Fig. 6). Iron and manganese tend to be more evenly distributed in the reducible, oxidizable, and residual fractions.

Surface crusts

Two types of efflorescent surface crusts found at the site were identified; a blue-green slightly crystalline crust found over much of the site whenever conditions were dry or drying, and a yellow, globular crust found only in late summer on a low bench near the creek where the water table is approximately 0.25 m below the surface. Metal concentrations in the water soluble fraction of the sediment are almost always highest at the surface (Fig. 5 and Fig. 6). Sequential extracts on crusts collected on two sampling days confirmed the crusts themselves are predominantly water soluble species (Table 3).

In addition, the blue crusts contain high copper and arsenic in the reducible fraction and lead in the oxidizable fraction (Fig. 7).

Water

Tensiometer data collected during this investigation revealed interesting soil water trends. Soil moisture trends were well defined at Site A. Only the shallowest tensiometers, at depths of 15 and 30 cm, show significant changes in relative soil water during the study period (Fig. 9). Soil water at and below 46 cm shows little relative change throughout the time of observation. A sharp decrease and subsequent gradual increase in negative soil water tension at the 15 cm deep tensiometer followed a heavy rainstorm (4.24 cm of precipitation) on July 5-6 (Fig. 8). The 30 cm tensiometer shows similar but smaller changes in response to precipitation. Deeper tensiometers show only a small change in response to the largest precipitation event. A seasonal trend is displayed by the upper 30 cm of the vadose zone, as it appears to dry out over the course of the summer (Fig. 9). The lower vadose zone shows no long term trend. Because the sediments in the middle and lower vadose zones are mainly coarse-grained, it is unlikely that a capillary fringe would extend more than a few centimeters up from the water table; therefor, the capillary fringe probably does not have a stabilizing influence on the soil moisture content in the middle and lower portions of the vadose zone. Soil moisture trends were less well defined at Site B (Fig. 10). The shallow vadose zone again shows the most variability in soil moisture and a seasonal drying trend, although response to precipitation events is not as straightforward. The tensiometers placed at 30 and 108 cm

showed slight response to the heavy rainstorm of July 5-6, but the 60 cm deep tensiometer did not. This may suggest that precipitation infiltrated to the 30 cm depth, and that the capillary fringe moved up to the 108 cm depth while there was little or no change in soil water content at the 60 cm depth. While direct water table measurements were not taken at Site B during this precipitation event, a water table increase of 23 cm was measured at Site A (Fig. 4). An increase of similar magnitude at Site B is reasonable and would bring the water table to approximately 115 cm depth. A capillary fringe of a few centimeters would increase the soil water content at 108 cm depth enough to explain the slight wetting seen on July 6th in the deepest tensiometer at Site B.

Vadose zone pore water was sampled using suction lysimeters. These instruments worked well most of the time, but occasionally, little or no water was pulled into the shallowest lysimeters, presumably because the soil was too dry (i.e. the tension on soil water adhering to vadose zone sediment was greater than the suction in the lysimeter). Merry and Palmer (1986), however, found no correlation between soil water and volume of water pulled into lysimeters. Also, the lysimeter at 87 cm depth, Site B, did not function properly for a few weeks because of defective tubing.

The pH of the pore water in the vadose zone decreases with depth, then increases sharply at the water table (Fig. 11 and Fig. 12). Over the sampling period, the pH ranged from 2.1 - 4.3 in the vadose zone to 4.4 - 5.6 in ground water at Site B and 6.0 - 7.3 in ground water at Site A.

Dissolved oxygen (Fig. 11 and Fig. 12) in the vadose zone pore water is high (5.2 - 8.3 mg/L). Dissolved oxygen measurements in the vadose zone are questionable because of

the method of sampling. All air is suctioned out of the lysimeter after sampling to allow the next sample to be pulled in, but it is likely that a small amount of air remains in the lysimeter and a small amount may leak in. Therefore, measurements should be interpreted with caution. However, it is reasonable to assume the vadose zone pore water is saturated with dissolved oxygen since the vadose zone is less than two meters thick and contains mostly sandy sediments and since sulfide oxidation is undoubtedly taking place. High dissolved oxygen measurements are in agreement with this assumption. Ground water contains very little if any dissolved oxygen (<1.7 mg/L or less as readings may be too high from slight contamination by atmospheric oxygen during sampling).

Dissolved ion concentrations are highest at 48 and 87 cm deep at Sites A and B, respectively (Fig. 11 and Fig. 12). The peak concentrations at Site A correspond to the minimum dissolved O_2 and maximum pH. At Site B, peak concentrations correspond with maximum dissolved O_2 and minimum pH. Clearly, each site has unique chemistry. Much lower dissolved ion concentrations are found in the ground water. Copper concentrations, for instance, decreases by two to four orders of magnitude from the vadose to ground water, and Mn by one to three orders of magnitude. Ion concentrations in ground water are inversely related to pH; ground water at Site A has higher pH than Site B, and it also has lower dissolved sulfate and metal concentrations.

Temporal pH trends are similar at both pore water monitoring sites, as are temporal trends in temperature (Fig. 13). The temperature of the vadose zone water increases in early summer and then stabilizes as spring warms to summer. The pH peaks at all depths in early summer and gradually declines throughout the rest of the sampling period.

There is a well defined temporal trend in dissolved constituents in the pore water at sampling depths of 55 and 114 cm at Site B that is not apparent at other depths at Site B or Site A. Dissolved constituents at Site A are relatively invariable throughout the sampling season, while at Site B, Cu, Fe, Mn, Zn, and SO_4 concentrations all decrease by as much as 50% until reaching a low at sampling date 6-16-94, then gradually increase in concentration and finally level off (Fig. 13). The lowest concentrations do not coincide with the peak in pH on sampling date 6-1-94. The lysimeter at 32 cm depth shows a similar trend, but it's low concentration is offset later in the summer than the 55 cm and 114 cm deep lysimeters. Lysimeter malfunction at 87 cm depth at Site B sometimes prevented sample collection; however, it appears that dissolved metal concentrations nearly doubled from the spring to mid-summer while pH decreased almost one unit (Fig. 13).

DISCUSSION

Highly contaminated soil water in the vadose zone of this mining impacted floodplain results from sulfide oxidation and subsequent release of sulfuric acid and metals. This contaminated water interacts with heterogeneous floodplain sediments to create a complex geochemical environment. Hydrologic processes further complicate the environment. Geochemical and hydrologic controls are most easily interpreted by describing the floodplain environment from the surface down through the vadose zone and into the ground water.

Soil water content changes indicate that only about 30 to 40 cm of the surface sediments in the vadose zone are significantly affected by seasonal or precipitation-

related events, and that water content in the deeper vadose zone is only very slightly effected by major infiltration of fresh water to the system. This conclusion is inconsistent with findings from a vadose zone moisture monitoring investigation done downstream near Anaconda (Land and Water, 1993). Soils in that study were somewhat similar (fine to medium sands and silts from settling ponds or sandy loam overlying extremely cobbly sand). They found that the depth to which precipitation and snow melt influenced the vadose zones was usually 61 to 107 cm, significantly deeper than the data suggest in the current study. Also, Titan Env. Corp. (1995) report that there is an estimated 7.6 to 8.9 cm of recharge to the water table via infiltration through the vadose zone. The data from this study are not in agreement with this. During the period of study, no recharge to ground water through the vadose zone was apparent. Direct recharge to ground water in the floodplain is probably limited to flood events or wet spring periods when vadose zone sediments can become saturated.

Seasonal trends in soil water content indicate that surface sediments dry out over the course of the summer (Fig. 9 and Fig. 10). This is consistent with the formation of efflorescent salts on the surface and greater metals in the water soluble fraction of the sediment in the upper 40 cm. Water which infiltrates into the upper 40 cm of the vadose zone is wicked up to the drying surface by capillary action, evaporates, and concentrates metals in the water soluble fraction and soluble efflorescent metal-sulfate crusts. When a large rainstorm occurs after a prolonged dry period in which efflorescent crusts have formed, the runoff dissolves the crusts and creates a huge input of acidic metal-rich water

to the surface water (Nimick and Moore, 1991). This phenomenon has been reported at other mining-impacted sites where "multicolored efflorescences" were reported (Filipek *et al.*, 1987). Mineral phases in the two types of efflorescent surface crusts found at the site are probably those identified downstream from the study site: gypsum ($CaSO_4 \cdot 2H_2O$), chalcanthite ($CuSO_4 \cdot 5H_2O$), boothite ($CuSO_4 \cdot 7H_2O$), melanterite ($FeSO_4 \cdot 7H_2O$), jarosite [$KFe_3(SO_4)_2(OH)_6$], and $ZnSO_4$ (Nimick and Moore, 1991). Alpers *et al.* (1994) describe the occurrence and properties of minerals found in crusts in mining-impacted systems. Hydrated iron sulfates ($FeSO_4 \cdot nH_2O$) were thought to form crusts on the surface of a tailings impoundment (Blowes and Jambor, 1990). Some or all of these minerals are most likely found at the study site. Copiapite [$Fe^{2+}Fe^{3+}(SO_4)_6(OH)_2 \cdot 20H_2O$], a mineral fitting the description of the yellow globular crust sampled at the Miles Crossing research site, is likely a major component in the yellow crusts (Jambor, 1994).

In addition to high water soluble metal concentrations in the upper 40 cm of sediment caused by evaporating soil water, Cores A, B, and E all show high concentrations of metals in the reducible, oxidizable and residual phases at this depth (Fig. 6). These cores have a surface clayey layer very high in organic carbon with underlying silty layers also high in carbon. Highest concentrations in the oxidizable portion of the sediment are found in the finer-grained, organic-rich layers due to a combination of mineralogy and binding by organic matter. The small average grain size of mill tailings, 4 μm - 2 mm, (Jambor, 1994; Robertson, 1994), suggests the finer-grained sediments represent more

tailings/sulfide-rich floodplain deposits. High carbon in the finer-grained layers suggests that organic matter has bound heavy metals in these layers. Increased concentrations of oxidizable phase metals would result from more sulfide minerals and metals bound by organics. Oxidation of sediment containing more sulfides would naturally create more oxyhydroxide and oxyhydroxysulfate coatings on that sediment, explaining the high reducible metals in the same fine-grained tailings/organic rich layers.

Similarity of lithology and metal concentrations in samples taken from the vadose zone between approximately 40 cm and the water table in Cores A and B suggests that processes may be relatively uniform across this zone (Fig. 6). Solid phases on the sediment may be somewhat resistant to dissolution and desorption reactions even where pH 2-3 water is in contact with them. Previous work on desorption of metals from oxyhydroxides done by Schultz *et al.* (1987) and Davis *et al.*, (1991) have shown that as the sorption - desorption process is repeated (i.e. pH is raised and lowered cyclically), an increasing fraction of metals remains sorbed to ferrihydrite, (i.e., it is less difficult to sorb metals onto sediment particles than it is to desorb them). Even the most tightly sorbed metals would be expected to desorb in the very low pH environment of the study site, but aqueous phase metals and sulfate actually decrease in this portion of the vadose zone even though pH is decreasing or very low (Fig. 11 and Fig. 12). Furthermore, the sequential extractions on the sediment clearly show that there is a measurable fraction of reducible sediment, probably oxyhydroxide coatings and sorbed metals, present throughout the vadose zone. Therefore, this middle portion of the vadose zone represents

a more "steady or stable" environment than either the shallow vadose zone or the water table zone.

The marked increase in reducible Cu, Mn, Fe, and Zn at the water table in Cores A and E is caused by precipitation of oxidized coatings as ground water of higher pH mixes with oxic, low pH vadose zone water (Fig. 6). Core B does not show this increase because ground water pH is low enough to keep more ions dissolved in the water (pH Site B = 4.4 - 5.6; Site A = 6.0 - 7.3, Site E = 6.3 - 6.4). Precipitation of oxide coatings is a well known phenomenon when *anoxic*, acidic ground water comes in contact with *oxic*, more neutral water (e.g. Benner *et al.*, 1995: Filipek *et al.*, 1987), but the Silver Bow Creek vadose zone system has *oxic*, acidic pore water coming in contact with *anoxic*, more neutral ground water. Some mixing of these two waters occurs during daily water table fluctuations, and extended mixing occurs during large water level changes such as those during floods or heavy precipitation events. It is likely that when mixing occurs, acidity is buffered by ground water and there is enough dissolved oxygen in the vadose water to precipitate iron oxyhydroxides. This is supported by the ferricrete layer at the water table. Other metal concentrations decrease because they are co-precipitating and/or adsorbing to the ferricrete.

Oxidizable fractions of Zn and Cu also increase at and below the water table in Cores A and E (Fig. 6). There is no indication that any more tailings or organic matter was originally deposited at the level of the water table than immediately above the water table, so aqueous chemistry must be influencing the sediment geochemistry. Microbiota

living on sediment grains may create a reducing environment conducive to precipitation of Cu and Zn sulfides (Gould *et al.*, 1994). Oxide precipitation may be occurring on the surface of grains when vadose and ground water mixing occurs, and simultaneously, sulfides may be precipitating (with the aid of bacteria) in micro-environments within coated grains. Benner *et al.* (1995) suggest sulfide precipitation in the ground water zone of Silver Bow Creek's mixing zone where dissolved oxygen is low and metal concentrations are high. The methods used in this study could not distinguish environments of this scale.

Sediment geochemistry data from the seven cores taken from the floodplain can be used to identify tailings distribution, pre-mining floodplain sediments, and reworked materials. Tailings are 1.75 m and 0.5 m thick at Sites A and D respectively, 60 m from one another. Between these two sites, the tailings are 1.5 m thick (Core E). This core is high in metals throughout, but at 1.5 m depth, cobbles from the pre-mining floodplain were encountered when coring. Pre-mining floodplain was sampled in Cores A and D (Fig. 5 and Fig. 6). It is represented by low concentrations of all elements in all fractions. Core C is located on a lower terrace near the stream. The low concentration of Zn in the upper 46 cm is typical of other metals such as Mn, Cu, Cd (Fig. 6). Because this core is located so near the river on a terrace only about 0.5 m above normal stream stage, it is probable that the upper 46 cm have been reworked over the past 100 years by small floods. Reworking would effectively "clean" the sediment by removing some of the tailings and depositing a mixture of un-enriched floodplain sediments and reworked tailings from upstream. Reworked sediments at the study site are analogous to the

"reworked channel deposits" identified approximately 20 km downstream by Nimick and Moore (1991). These sediments have metal concentrations intermediate between pure tailings and un-enriched floodplain sediments. Lateral heterogeneity, demonstrated by the contrast in metal concentrations in the upper 60 cm of Core D as compared to other cores, can be attributed to heterogeneous floodplain stratigraphy.

Metal partitioning between oxidizable and reducible solid phases can be used to describe the state of the floodplain. Zinc, Cd, and Pb predominantly partitioned into the oxidizable phase which suggests there are abundant sulfides of these elements left in the floodplain to oxidize. Solid phase Cu is partitioned more evenly into both oxidizable and reducible phases. These data suggest that Cu sulfides have undergone quantitatively more oxidation than sulfides of Zn, Cd, and Pb, so Cu now resides comparatively more in oxidized coatings (high Cu concentrations in reducible solid phase) than do Zn, Cd, and Pb. Iron and manganese tend to be more evenly distributed in the reducible, oxidizable, and residual fractions, indicating these metals are present in solid oxidized and reduced forms and in silicate minerals.

Iron chemistry of the pore water in the vadose zone and shallow ground water is controlled by pH, soil water trends, and sediment geochemistry. There is less than 2 ppm iron in the water when pH is above 3.5 (shallowest sampling points), but when pH is at or below 3.5 iron increases to 2 - 3600 ppm (Fig. 11 and Fig. 12). An exception to this occurred on June 1 at Site A (Fig. 11) where up to 15 ppm Fe is dissolved in the water at pH 3.9. Davis *et al.* (1991) give 3.5 as the pH at which iron oxyhydroxides will begin dissolving and iron will be present as Fe^{3+} in oxic water, and 2.2 as the pH at which the

maximum dissolved iron concentrations were observed in laboratory desorption experiments. As pH in the vadose zone falls below 3.5, iron oxyhydroxide coatings on the sediment and metals that were sorbed to them, dissolve, explaining the peak in dissolved Cu, Mn, and Zn at 48 cm at Site A (Fig. 11). Although pH is low, Cu, Mn, Zn and SO_4 concentrations decrease below 48 cm because of resistance of the coatings to desorption and dissolution as described above.

Mn, Zn, and Cu concentrations in ground water are pH controlled. Most research on adsorption of heavy metals by soils, sediments, and iron oxyhydroxides shows the order of desorption of metals as pH decrease is Mn, Zn, Cu (Elliott *et al.*, 1986; Davis *et al.*, 1991). As pH decreases, Mn desorbs first and Cu desorbs last. This explains why Mn concentrations are about 10 ppm higher than Zn concentrations which are 2-10 times those of Cu for ground water sampling points. Mn and Zn are more completely desorbed from the sediment than Cu in the ground water.

Dissolved iron must be present as Fe^{3+} in the vadose zone according to the reaction:

$$Fe^{2+}(aq) + 0.25O_2 + H^+ \xrightarrow{\text{bacteria}} Fe^{3+}(aq) + 0.5H_2O \qquad pH<3$$

where oxygen is present and pH < 3, but iron in ground water, where pH ranges from 4.5 - 7.3, must be present as Fe^{2+} since Fe^{3+} is only very slightly soluble above pH 3. Also, there must be no oxygen dissolved in the ground water, because if oxygen is present, it will rapidly oxidize the Fe^{2+} to Fe^{3+} (Nordstrom, 1982) which would precipitate in ground water pH's. It is likely that oxygen is being consumed by microbes living at the ground water/vadose zone interface. Dissolved oxygen measurements of 0.5 mg/L taken

with an Orion oxygen electrode are probably high and only represent the detection limit of the electrode.

Temporal trends in water chemistry of the vadose zone depend partly on seasonal changes. The temperature of the vadose zone water increases in the spring as the ground thaws, and then levels off as summer temperatures reach normal (Fig. 13). The pH peak around June 1 may be due to dilution of existing vadose water as spring runoff infiltrates into the upper vadose zone (Fig. 13); however, soil water content in the shallow vadose zone was not monitored prior to June 1 so this hypothesis is based on the assumption that the vadose zone dries out yearly, and is replenished in the spring. The subsequent pH decrease indicates increasing oxidation of sulfides after the spring thaw and/or infiltration of metals dissolved from surface salts during precipitation events.

The well defined trend in dissolved constituents in the pore water at sampling depths of 55 and 114 cm at Site B, and less defined trend at 32 cm are indicative of complex geochemistry. The lowest concentrations do not coincide with the peak in pH on sampling date 6-1-94, as would be expected if pH was the dominant control on concentrations. Sampling frequency may be such that the actual peaks in pH and lows in concentration are not being sampled but do occur at the same time. Or there may be a lag time between pH highs and minimum dissolved concentrations. The fact that the trend is only visible at two out of nine sampling points may indicate a very localized phenomenon. Possibly, these lysimeters are placed in sedimentary layers which are retarding the rate of precipitation so that increasing pH does not immediately decrease metal concentrations. Poorly understood processes in stratigraphic micro-environments

may be the reason for discrepancies between the temporal trend in pH and metal concentrations at these two depths.

CONCLUSIONS

Hydrologic and geochemical controls on metals partitioning in the vadose zone and shallow ground water zone of the Silver Bow Creek floodplain include stratigraphy and mineralogy of the sediments, soil water trends, fluctuations of the water table, and ground water chemistry.

Flood deposition and subsequent reworking of tailings on the floodplain has created variable tailings thickness across the site. Fine-grained, metal-sulfide-rich, organic-rich layers are interstratified with coarser-grained sediment. Tailings thickness is variable across the site and reworking of floodplain sediments has reduced total metal concentrations in some sediments. Presence of a surface clayey layer prevents deep infiltration of precipitation, but the upper 40 cm of the vadose zone does receive some infiltration. As the surface of the floodplain dries out, the soil water is wicked up to the surface by capillary action, carrying dissolved metals and sulfate with it. When the water evaporates, it leaves behind precipitates of water soluble salts in the upper 40 cm of the vadose zone and as efflorescent surface crusts. Fine-grained, organic-rich tailings in the upper 40 cm contain high metal concentrations because they likely have more original sulfide minerals in them, organic matter is binding the metals, and more oxidation products are found with the original sulfides as oxyhydroxide coatings. Pore water in the upper vadose zone is more dilute (higher pH and lower metal and sulfate concentrations)

than the water lower in the vadose zone because infiltration supplies fresh, uncontaminated water to the upper 30 cm.

Movement of the contaminated water downward into the ground water did not occur during the study period. Ground water contamination from the vadose zone does occur when daily and seasonal water table fluctuations bring the water table up into sediments that were previously in the highly oxic vadose zone. Reduced ground water mixes with water much higher in dissolved metals and oxygen and lower in pH. If there is enough oxygen present, the increased pH will cause iron to precipitate as ferrihydrite. Other metals (Cu, Mn, Zn, Cd, Pb) will coprecipitate or adsorb to the newly formed surfaces, creating a zone of increased metal concentrations in the reducible fraction of the sediment at the water table. If the ground water pH is lower, i.e. 4-5, and the reduced character of the ground water dominates the vadose zone water, iron will be reduced to Fe^{2+} and remain in solution along with other metals. Because these sediments are now coated with ferricrete, sulfide oxidation may be somewhat hindered. Micro-environments within the shallow ground water zone may enable both precipitation of oxides and sulfides.

The pore water in the vadose zone just above the water table is renewed by water table fluctuations, and infiltration renews water in the upper 30 - 40 cm, but water between these two zones is relatively stagnant through most of the summer and fall. Soil water in the middle vadose zone may only be replenished during floods or very wet periods. The high residence time of water here explains why it has the lowest pH and is highly contaminated. Relatively uniform metals partitioning in the solid phase throughout this

zone (30 cm to water table) is likely due to lack of large soil water variations, resistance of the sediments to metal desorption by low pH water, and the fact that this zone is not as heterogeneous as the upper part.

Ground water chemistry is controlled by pH and dO_2. Higher pH waters contain lower concentrations of dissolved ions than do low pH areas. Variable levels of desorption, controlled by pH, account for different amounts of metals in the ground water (dissolved Mn > Zn > Cu in the aqueous phase because Mn desorbs more than Zn which desorbs more than Cu at a given pH). The bulk ground water at both sites is somewhat reducing (low dissolved oxygen) but not enough to precipitate metal sulfides (dissolved Fe^{2+}, Mn, Zn, Cu quite high). However, there may be micro-environments in which conditions are more oxidizing or reducing.

Characteristic partitioning of metals into preferred phases throughout the floodplain indicates that sulfides of Zn, Pb, and Cd are still very abundant throughout the floodplain and remain to be oxidized. Also, Cu has undergone more complete oxidation than other sulfides and is present in sulfides, oxyhydroxide coatings, and soluble salts.

These conclusions can aid in designing an effective remediation strategy for the Silver Bow Creek floodplain. The lack of vegetation allows the upper 30 cm of sediment to be infiltrated and consequently enriched by upward movement of metal rich soil water as drying occurs. The acute contamination of the stream by large run-off events dissolving those surface metals could be reduced if the surface sediment could be stabilized with vegetation (by first liming it). This would also reduce wind-blown contaminated dust. However, liming would increase permeability and thus increase infiltration. A vegetated

clay-rich cover may inhibit infiltration while stabilizing surface sediment. Long-term contamination of ground water by oxidation of sulfides is much harder to remediate. Sulfides present at the water table present the potential for ground water contamination well into the future. Continuous stream water contamination by inflowing ground water is inevitable as long as sulfides are present in this oxidizing environment. If the tailings are left where they are, "nature will take it's course" and the metals will be re-incorporated back into the earth's cycle. This is a slow process and Silver Bow Creek would likely remain contaminated for a very long time, but this may be an acceptable, low-cost solution, provided precautionary measures are taken to limit human contact with contaminated waters and sediment. Alternatively, the tailings could be re-mined to extract the valuable metals. Two problems prevent this: 1) direct mining of floodplain soils is difficult as long as they are classified as hazardous waste under CERCLA, 2) the metal-sulfides in the tailings are now coated with oxyhydroxides making them resistant to mining extraction processes. If these restrictions are eventually worked out, more complete remediation of the Silver Bow Creek floodplain may be possible.

TABLES AND FIGURES

Table 1. Most common and important sulfides present in the Butte mining district.

(after Meyer, *et al.*, 1968)

NAME	FORMULA
Most common sulfides	
Bornite	Cu_5FeS_4
Chalcocite	Cu_2S
Chalcopyrite	$CuFeS_2$
Covellite	CuS
Digenite	Cu_9S_5
Enargite	Cu_3AsS_4
Galena	PbS
Molybdenite	MoS_2
Pyrite	FeS_2
Sphalerite	ZnS
Tennantite	$Cu_{12}As_4S_{13}$
Minor sulfides with toxic metals	
Acanthite	Ag_2S
Arsenopyrite	$FeAsS$
Colusite	$Cu_3(As,Sn,V,Fe,Te,)S_4$
Greenockite	CdS
Proustite	Ag_3AsS_3
Pyrargyrite	Ag_3SbS_3
Stephanite	Ag_5SbS_4
Stromeyerite	$CuAgS$
Wittichenite	Cu_3BiS_3

Table 2. Quality control and quality assurance summary

		Al	As	Ca	Cd	Co	Cu	Fe	Mg	Mn	Mo	Na	Ni	Pb	Si	Sr	Ti	Zn	SO4	C
Field Dup. Aqueous	% of analyses	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	4	NA
	avg. % difference	8	12	8	14	7	6	5	3	9	20	5	25	20	9	15	5	7	3	NA
Field Blanks	% of analyses	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	9	NA
	# exceeding IDL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	NA
Internal Stds.	% of analyses	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	20	NA
	%difference	14	24	14	13	13	12	11	9	10	14	17	15	18	19	17	9	11	9	NA
External Aq. Stds. (2)	% of analyses	3	8	4	10	2	8	4	4	4	2	4	8	0	4	4	0	4	20	NA
	%difference	47	19	24	27	38	4	17	18	21	17	11	7		28	7		23	9	NA
External Sed. Stds. (3)	% of analyses	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	NA	30
	Max. % error	6	30	7	53	36	12	8	-3	16	2683	8	9	19	-7	19	-28	11	NA	5
	Min. % error	-10	-32	-9	-18	8	-23	-7	-10	-5	236	-13	-11	-19	-18	-17	-42	-7	NA	5
	Average % error	-3	8	-1	17	23	-9	-3	-7	2	1483	-2	-5	1	-12	-2	-34	3	NA	5
Laboratory Blanks	% of analyses	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	8	NA
	# of analyses	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	13	NA
	# exceeding IDL(1)	1	0	2	0	0	8	1	0	1	0	10	0	0	1	0	0	1	0	NA
	value of worst exceedence (mg/L)	0.076		0.17			0.25	0.051		0.1		0.55			0.29			0.22		NA
Lab. Duplicates - Aq.	% of analyses	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	8	NA
	avg. % difference	-1	-16	0	-1	-1	-1	0	0	1	0	-1	1	2	-3	1	1	-1	4	NA
Lab. Duplicates - Sed.	% of analyses	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	NA	NA
	avg. %RSD	3	-1071	3	5	12	1	3	2	2	31	2	24	-53	3	1	25	2	NA	NA
Sed. Extract .Reps. (4)	% of analyses	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18		30
	max. %RSD	46	*530*	47	*278*	*96*	34	65	49	42	*10719*	*507*	*1262*	*1103*	38	27	*178*	126	NA	10
	avg. %RSD	9	*-11*	10	*17*	*18*	8	9	9	8	*257*	35	*38*	*26*	9	7	*7*	10	NA	4
	% replicates >12%RSD	26	*63*	26	*49*	*44*	21	16	23	14	*30*	*49*	*63*	*37*	30	16	33	23	NA	0
Spike additions	% of samples	9		12	7		6	11	13	8		11			13			*8*	5	NA
	% conc. spiked	20-422		48-478	53-430		37-352	9-414	50-463	8-356		23-101			2-446			25-264	48-201	NA
	% spike recovery	90-107		92-113	100-115		94-112	94-115	91-107	93-112		88-113			90-114			82-111	99-104	NA
Sum of seqential extract's vs. total digests	Avg. "%recovery"	102	105	109	98	94	103	105	101	107	109	99	-4740	104	87	103	94	98	NA	NA

1 = IDL = instrument detection limit

2 = EPA Split WS028, USGS Std. T115, and USGS Std. T117 were used for ICP standards. USGSM90, USGSM104, USGSM106 were used for IC standards.

3 = NIST 2710 is the Nat'l Institute of Standards and Technology's standard reference material 2710, Montana soil, highly elevated trace element concentrations.

3 = NIST 2711 is the Nat'l Institute of Standards and Technology's standard reference material 2711, Montana soil, elevated trace element concentrations.

4 = Replicates with very small concentrations (<4 times the IDL) are shown in italics. Because of the small concentrations %RSD's are relatively poor. Metals in sediment concentrations for these elements should be interpreted as approximate.

Table 3. Concentrations of water soluble metals in surface crusts.

	Weight %		μg metal/g sediment				
	Fe	**Ca**	**Zn**	**Mn**	**Cu**	**Cd**	**Pb**
Blue crust - July 1	0	2.8	9,300	6,100	2,000	32	0
Blue crust - Sept 19	0	2.2	16,000	9,100	2,800	85	0
Yellow crust - Sept 19	6.2	1.8	7,700	7,600	4,000	26	68

Fig. 1 - Miles Crossing Research Site Location

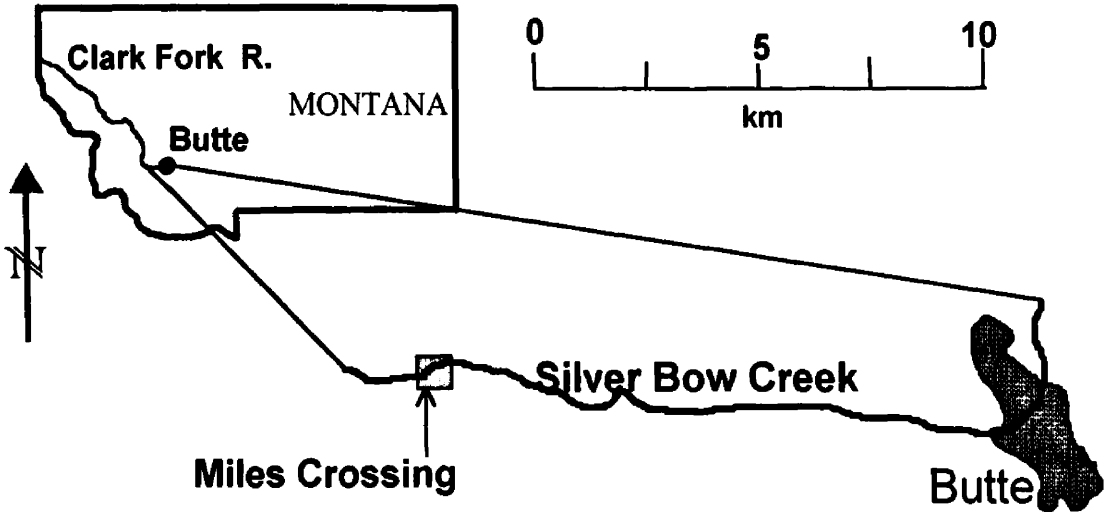
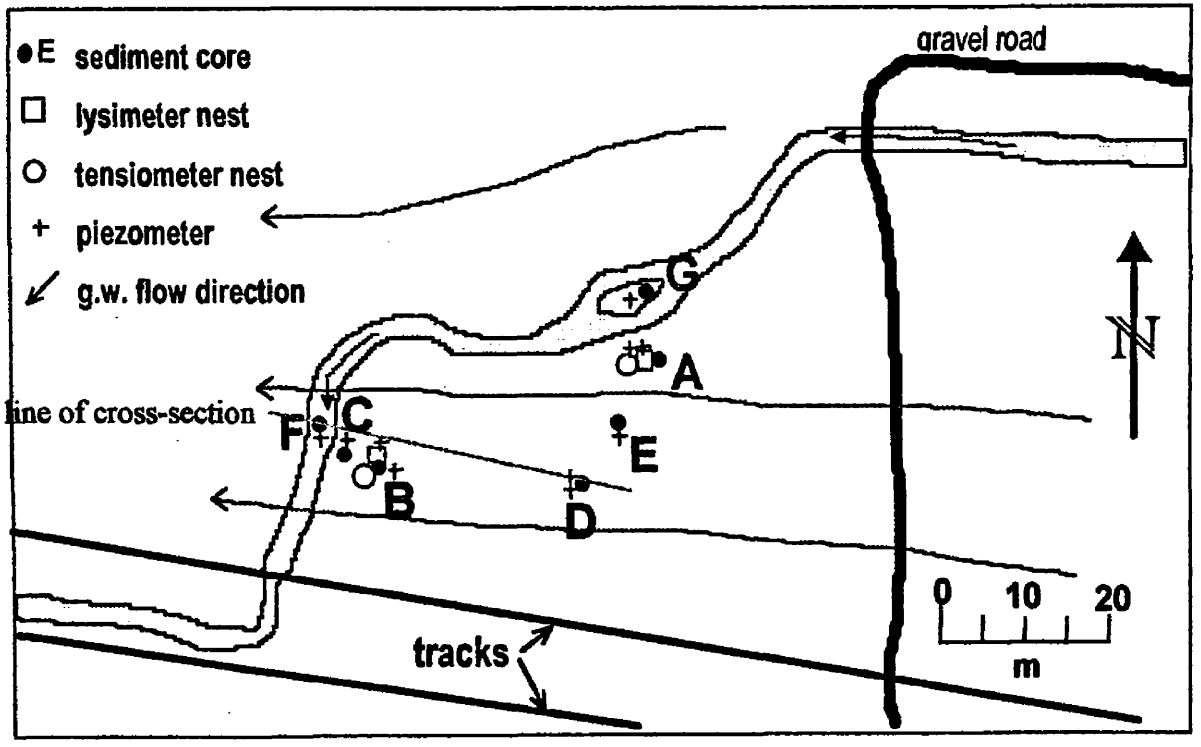


Fig. 2 - Silver Bow Creek - Miles Crossing Research Site Map



See Appendix for Additional Site Identification and Locations.

Fig. 3 - Generalized Cross-section through Silver Bow Creek and Floodplain.

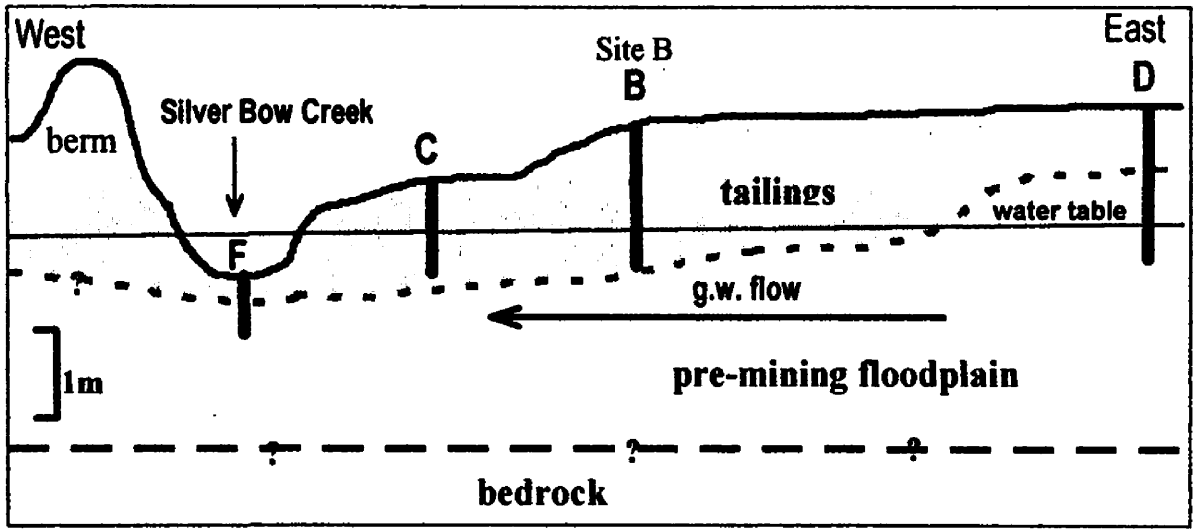
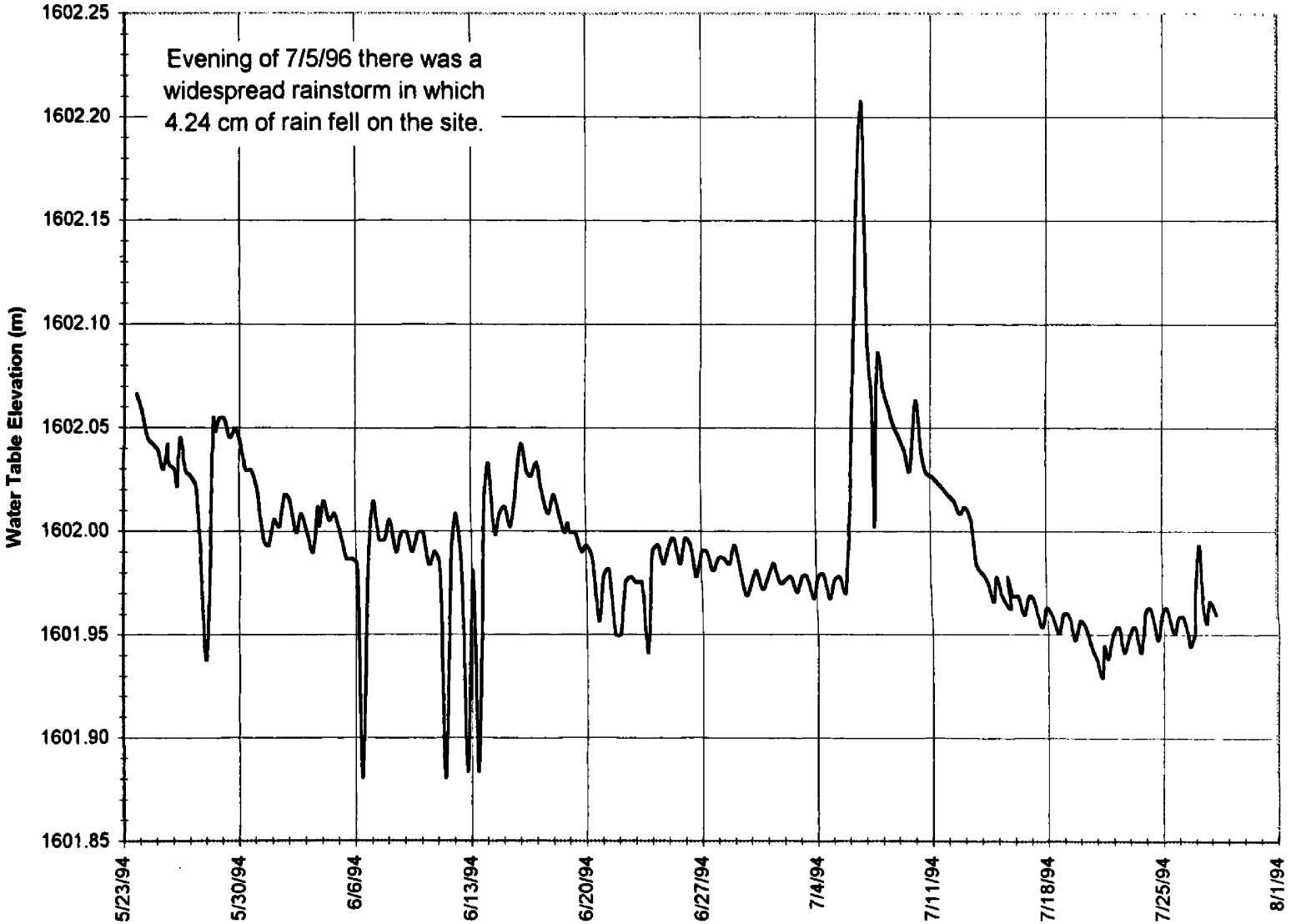


Fig. 4. Water Table Fluctuations at Site A approximately 5 m from Creek

measured with a Steven's Continuous Chart Recorder



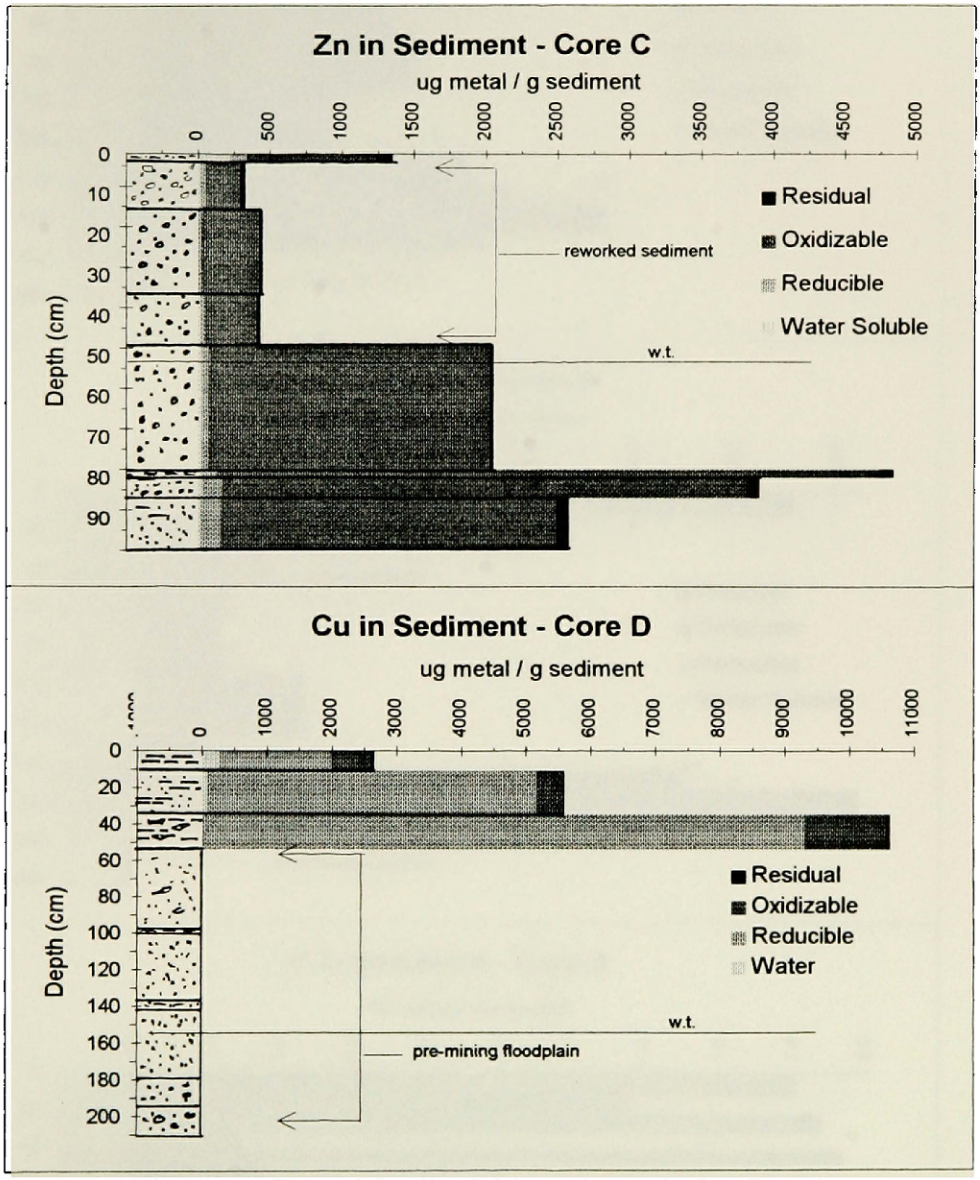


Fig. 5. Position of pre-mining floodplain and reworked sediments.
w.t. = water table position.

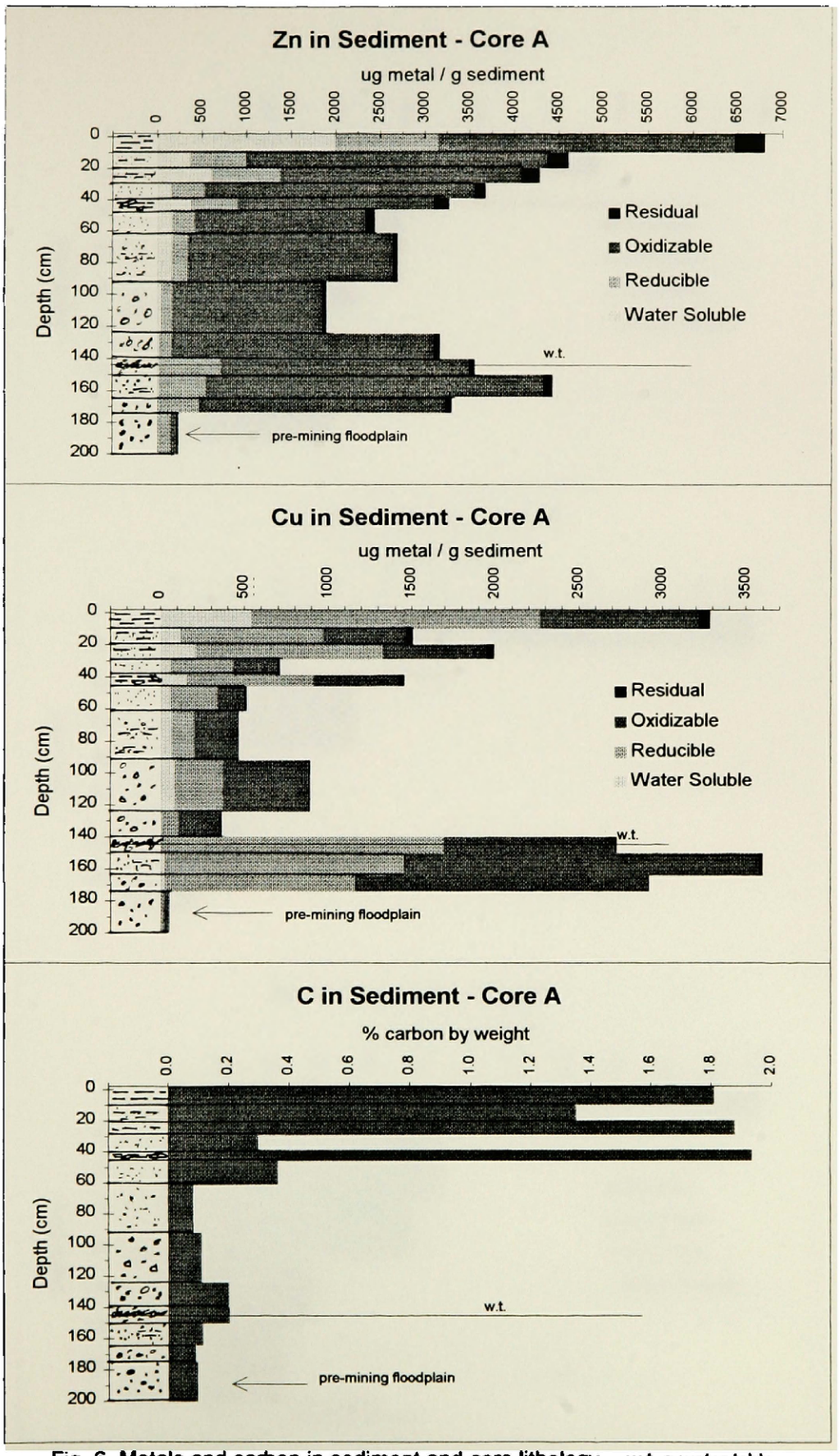


Fig. 6. Metals and carbon in sediment and core lithology. w.t. = water table.

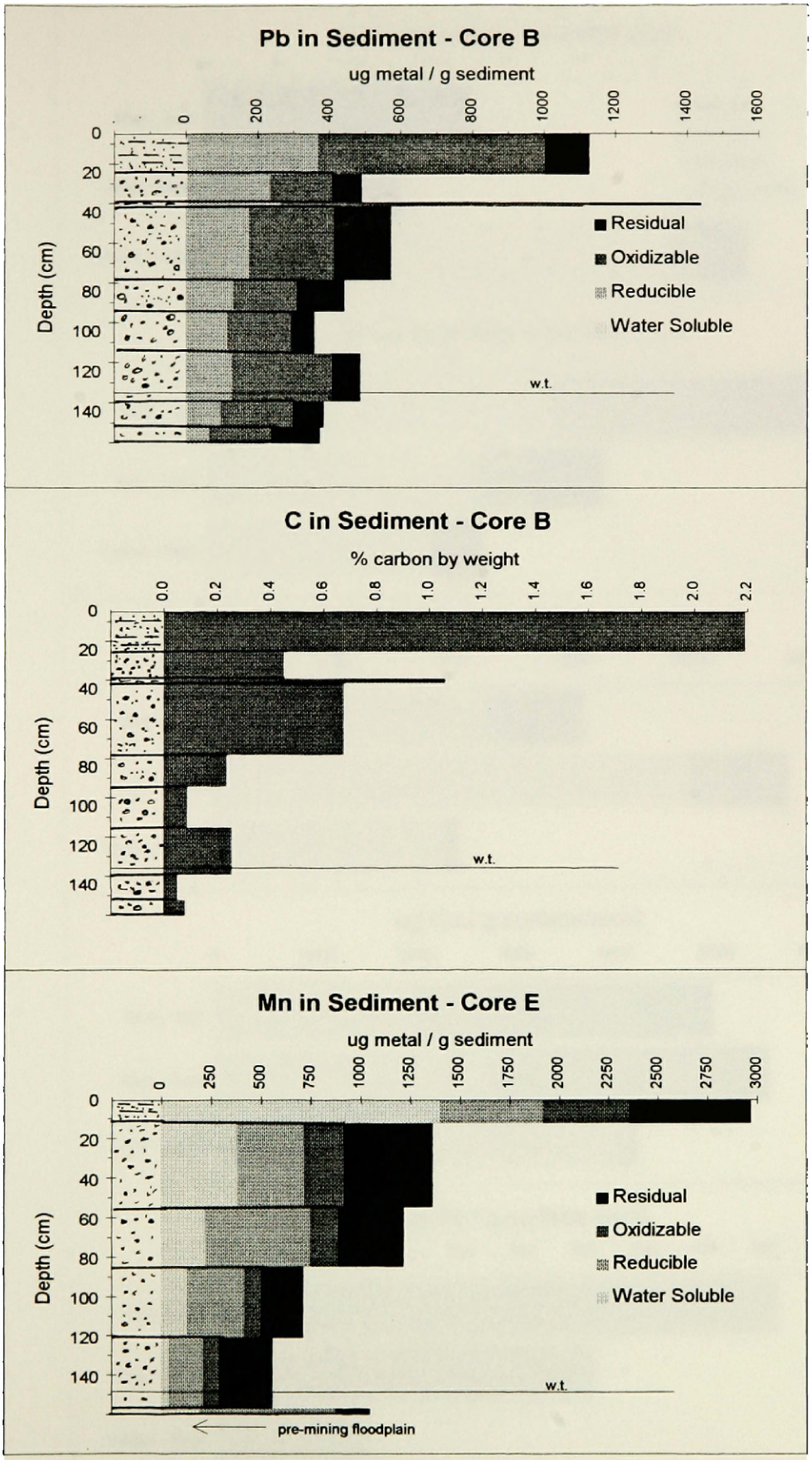


Fig. 6.(continued) Metals and carbon in sediment and core lithology.

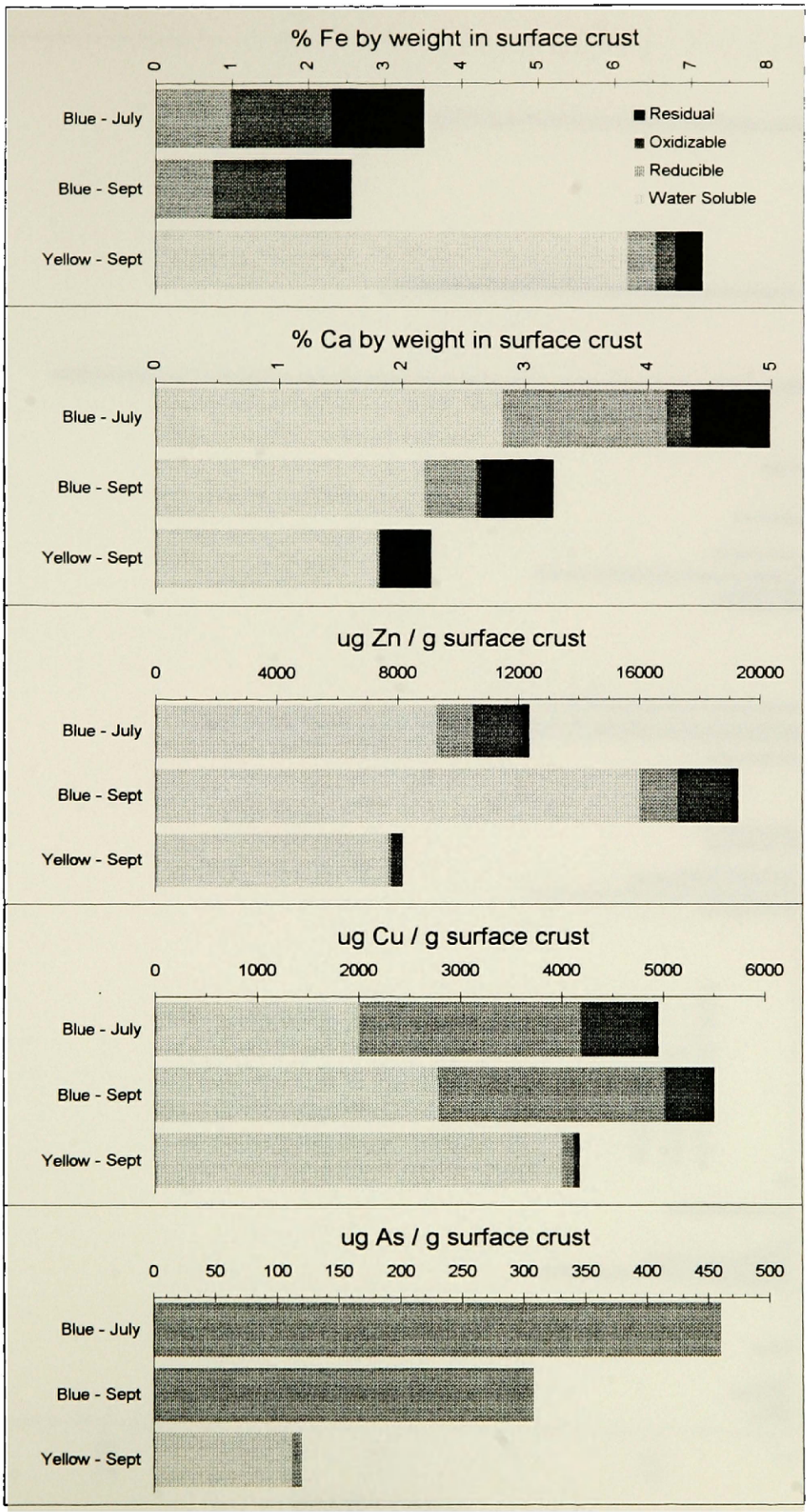
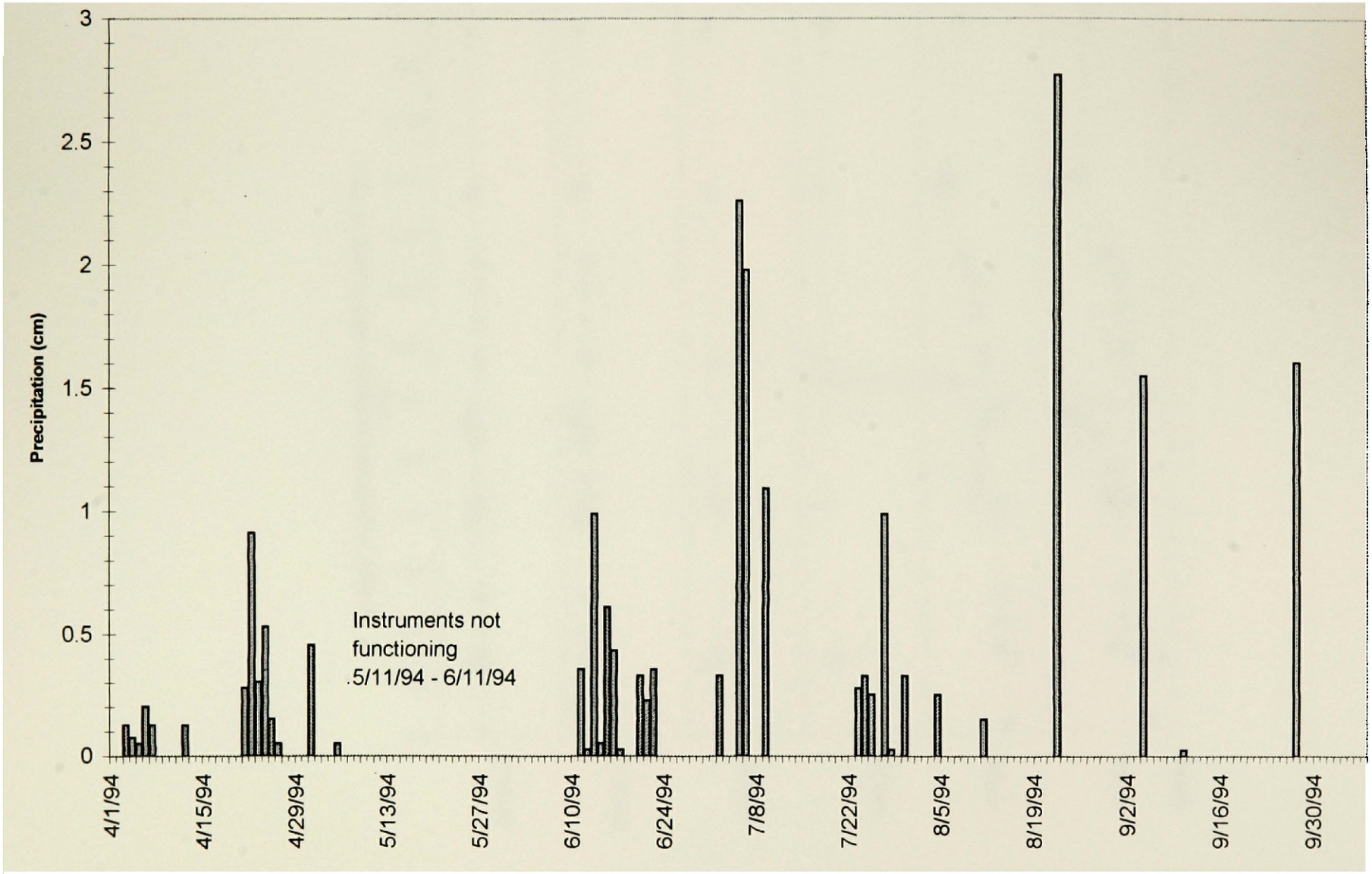


Fig. 7. Metals partitioning in efflorescent surface crusts. (10,000 ug = 1 wt. %.)

Fig. 8. Precipitation at the Miles Crossing - Silver Bow Creek Research Site



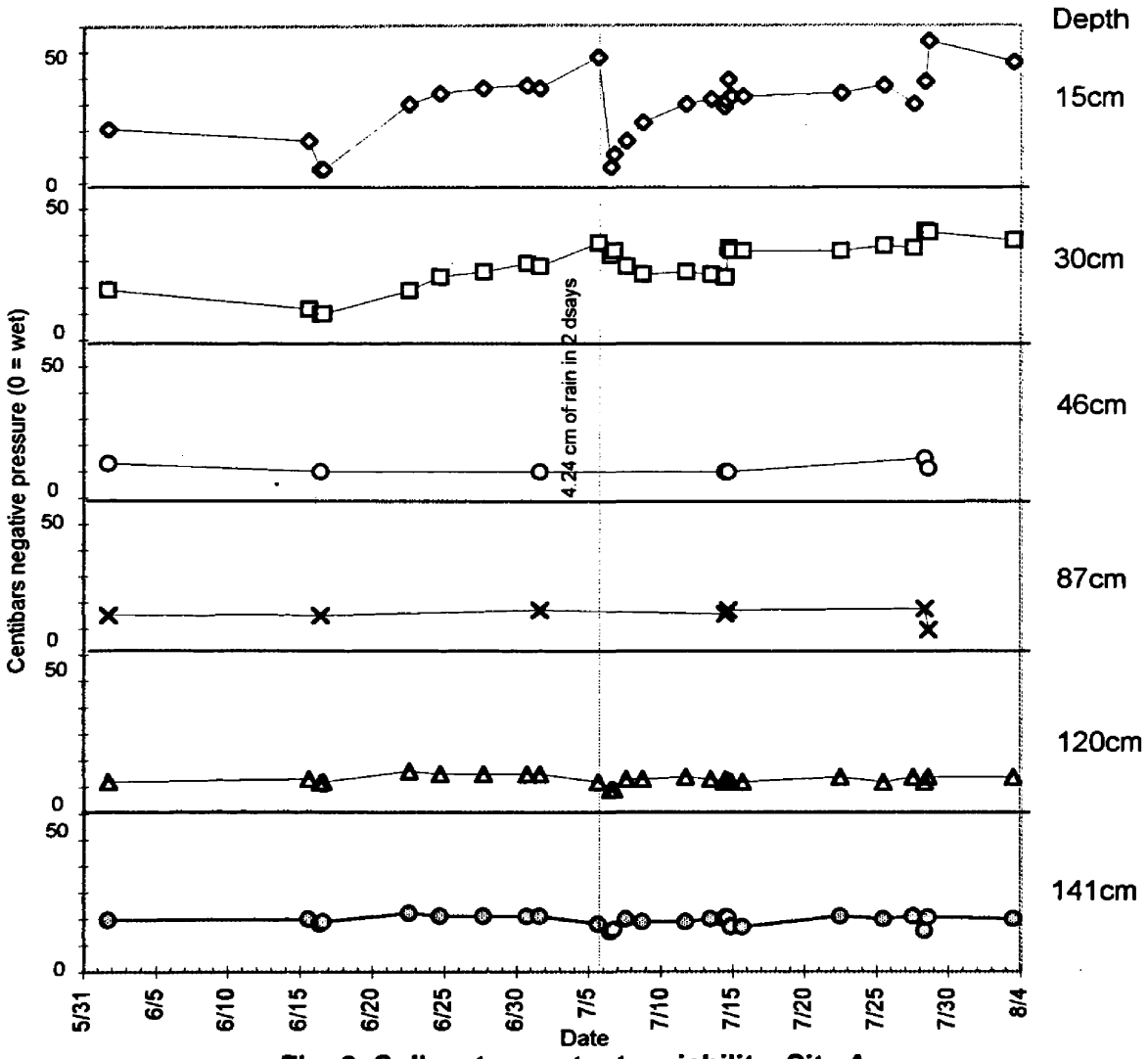


Fig. 9. Soil water content variability, Site A

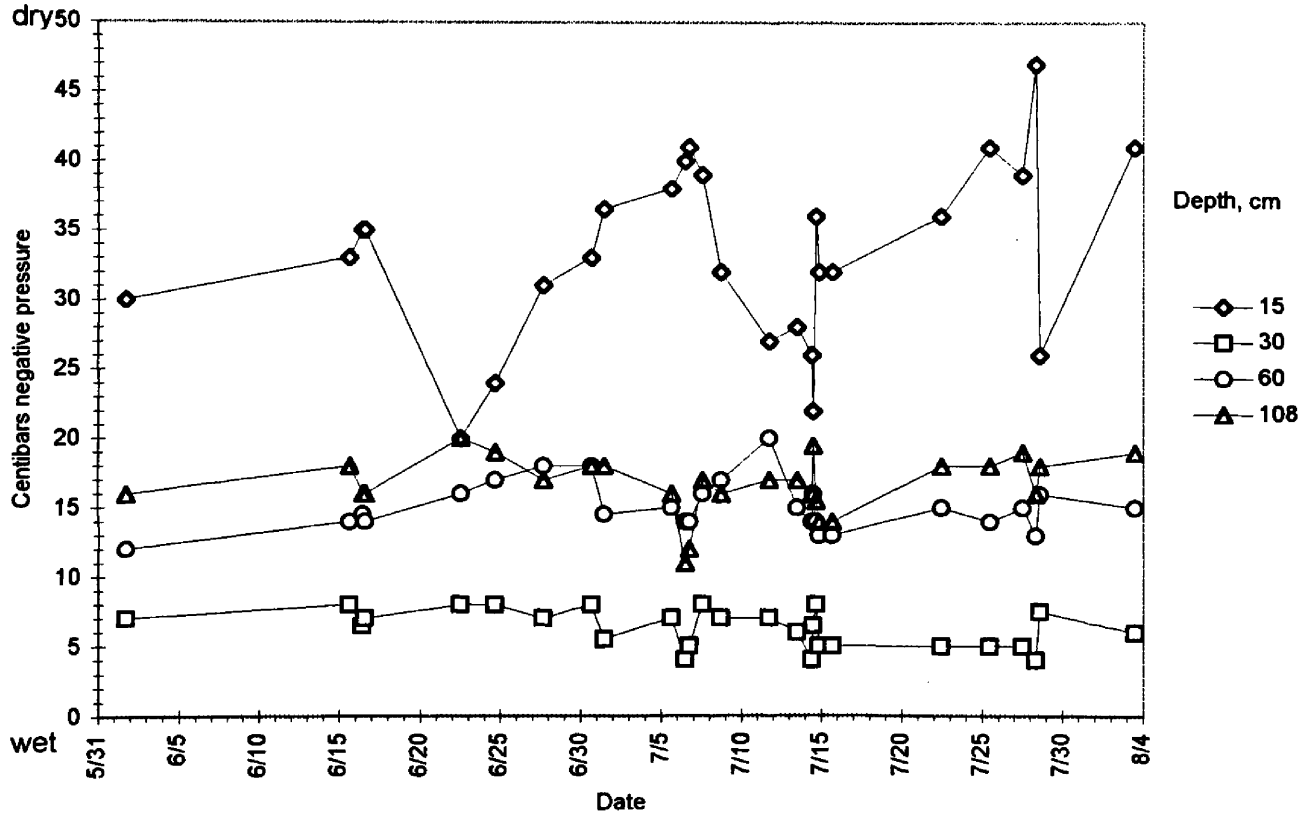


Fig. 10. Soil water content variability, Site B.

Fig. 11. Water chemistry **Site A. 6/1/94**

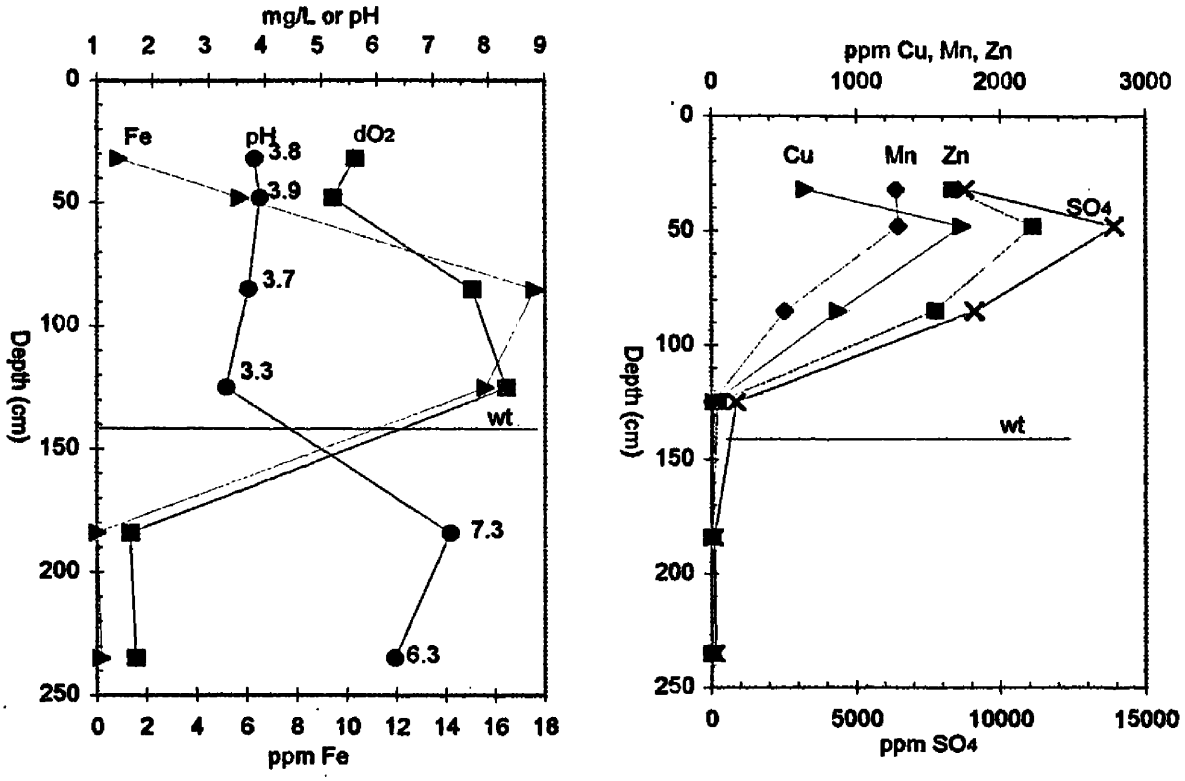


Fig. 11. Water chemistry **Site A. 7/28/94**

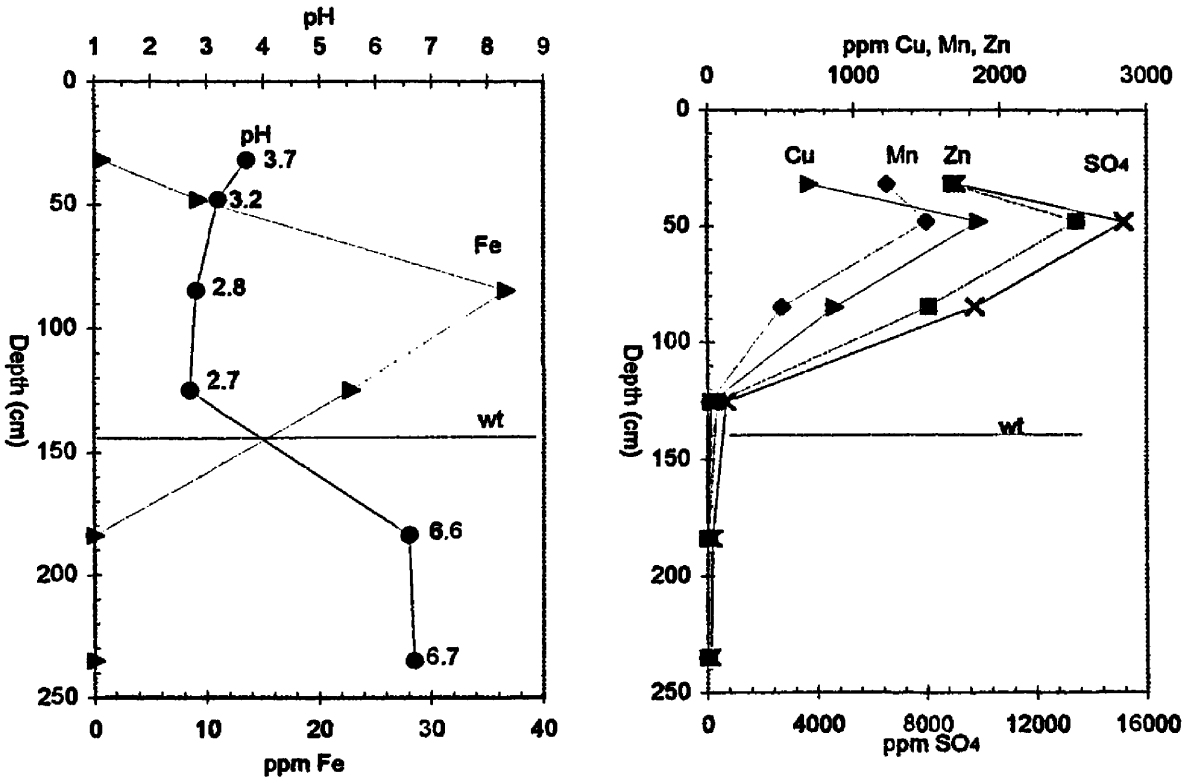


Fig. 12. Water chemistry Site B. 5/27/94

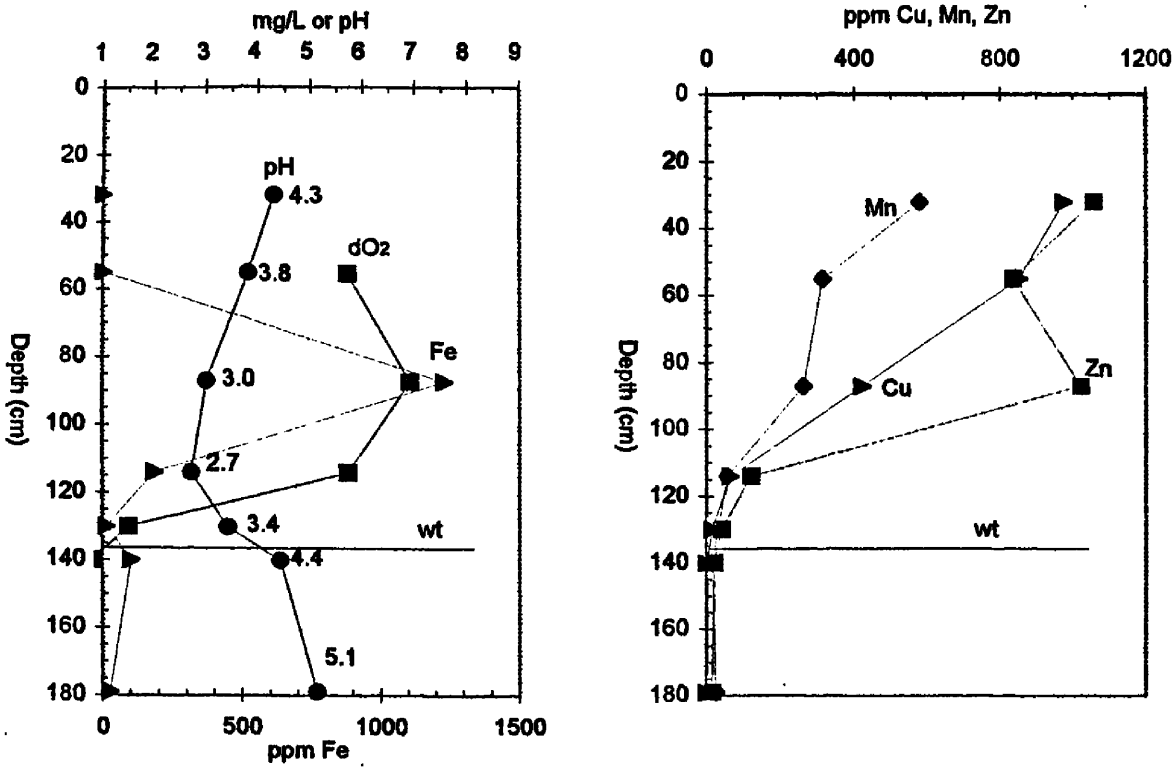
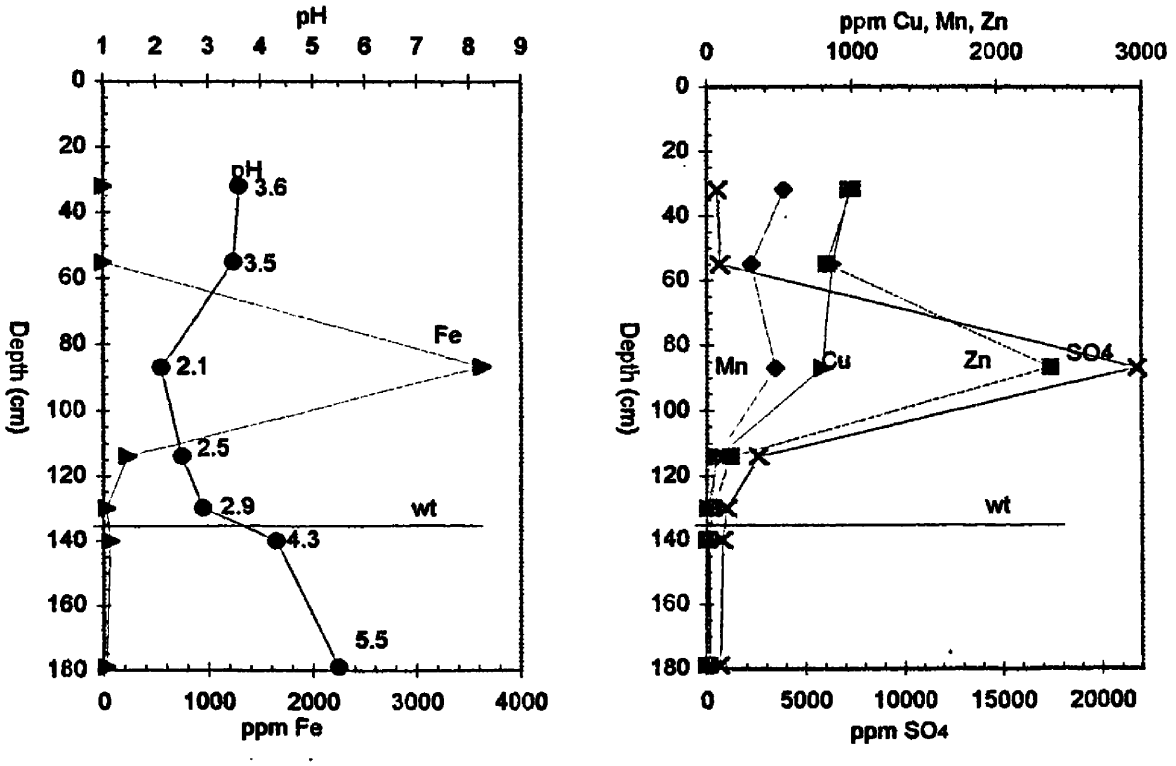


Fig. 12. Water chemistry Site B. 7/28/94



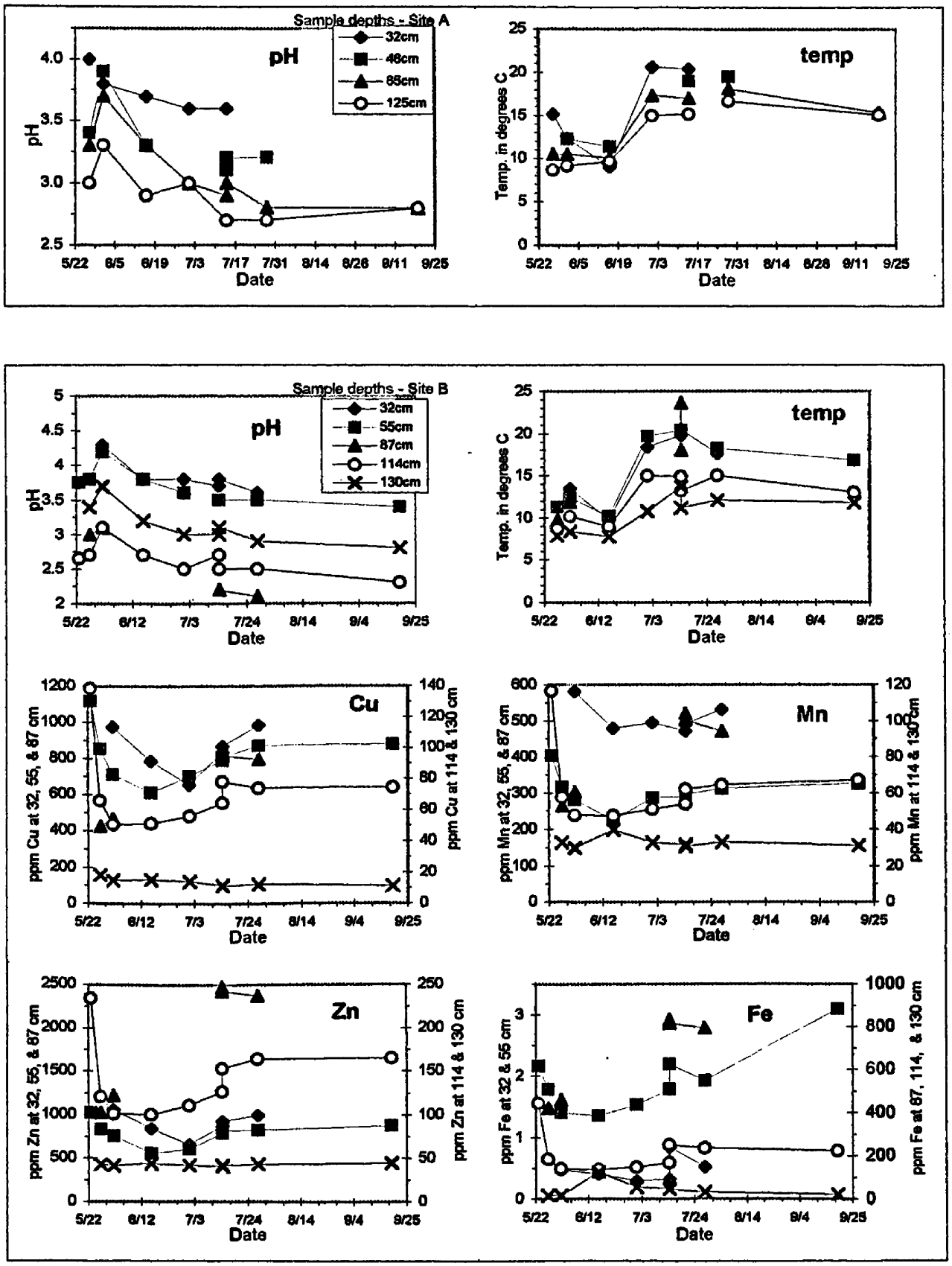


Fig. 13. Temporal trends in pH, temperature, and dissolved cation concentrations throughout study period at Site A (top) and Site B (bottom). Breaks in data due to lysimeter malfunction.

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APPENDICES

Appendix of Methods

Correction of core compaction

Compaction of the sediment occurs during coring. I did calculations to "re-expand" the core so that I would be interpreting the samples at their real depth. I assumed uniform compaction over the length of the core. The formula I used is:

"real" sample depth = sample thickness x (total core depth/core length) + above layer's bottom depth

Key to sample names and abbreviations

BIDL = below instrument detection limit

Vadose zone samples
Vadose zone pore water samples from lysimeters are named using the following format:

[Site Letter Designation]["L" for lysimeter][depth of lysimeter in cm]

and, if appropriate, with "2nd" after the name to denote that sample was the 2nd sample from that lysimeter on that date.
E.g. **AL048 2nd** would be the second sample taken from the lysimeter at 48 cm depth below surface at Site A on that date.

Ground water samples
- Piezometers are designated by a "P" and the number of that piezometer. See Appendix of Photographs and Detailed Site Maps for locations.
- Larger (4-6 inch) wells are designated with "MW" and a number.
- Small tube sampling ports used by Benner (1994) and sampled during this study are designated by a "B" followed by a location number and a depth of port in feet.

Surface water samples
- Surface water was sampled at three sites shown on the Detailed Site Maps. Abbreviations are as follows:
- MXing = Silver Bow Creek at the Miles Crossing automobile bridge.
- RRBrdg = Silver Bow Creek at the railroad bridge on the west end of the study site
- B-line Ck = Silver Bow Creek at the "B-transact" NW of the Site B near wells P49, P51, P61.

Sediment samples
Sediment samples are named with the sediment core's letter designation followed by the depth of the sample in cm. Depth is the calculated depth corrected for compaction during the coring procedure. Core locations can be found on Fig. 2 or in Appendix of Photographs and Detailed Site Maps. As sediment samples went through the sequential extraction and total digestion procedures, they a number and letter were added to the name to denote which extraction that liquid fraction was from according to the following key:
1W = water soluble extraction
2R = reducible extraction
3O = oxidizable extraction
4Z = residual extraction
5T = total digestion
Note: Sample D100-180 is actually the sediment from 100 to 180 cm deep in Core D less the sediment from 138-141. The sediment between 138 and 141 cm was a clay layer. This sediment was removed from the core as a separate sample, then the sediment from 100 to 180 cm was homogenized into one sample.

Total and sequential extraction procedure

All extractions done on ground sediment samples.

I. SEQUENTIAL EXTRACTION

A. WATER SOLUBLE FRACTION

1. weigh 0.5 g sediment into a 50 ml centrifuge tube
2. add 20 ml milli-q
3. shake for 12 h
4. centrifuge at 3500 rpm for 20 min.
5. decant liquid into plastic 2 oz. bottle for analysis
6. acidify the sample with 2 smallish drops of HNO_3

B. REDUCIBLE FRACTION

1. to the sediment in the centrifuge tube, add 10 ml 0.25 M hydroxylamine hydrochloride in 25% (v/v) acetic acid (glacial, trace metal grade)
2. shake for 12 h
3. centrifuge for at 3500 rpm for 20 min.
4. label and weigh enough 2 oz. bottles
5. decant the liquid into bottle for analysis
6. rinse - to the remaining sed in the centrifuge tube, add 10 ml milli-q and shake by hand for approx. 10 seconds; centrifuge as above; decant the liquid into the reducible sample
7. dilute that with milli-q to 50 g on the scale

C. OXIDIZABLE FRACTION

1. to the sediment in the centrifuge tube, add 0.5 g potassium chlorate (ACS grade MCB reagents)
2. add 10 ml hydrochloric acid (trace metal grade) [DO THIS IN THE HOOD]
3. let stand for ½ h
4. add 10 ml milli-q
5. shake for 12 h
6. centrifuge as above
7. label and weigh enough 2 oz. bottles
8. decant liquid into bottle for analysis
9. repeat steps 1 through 7, adding second liquid to the first
10. rinse - as above, adding rinse water to oxidizable sample
11. weigh to determine dilution (usually over 50 g but if not, add milli-q to 50 g)

D. RESIDUAL FRACTION

1. weigh enough 120 ml Teflon reaction vessels
2. transfer remaining sediment from centrifuge tube to the Teflon reaction vessel by "power washing" it out with a milli-q squirt bottle
3. centrifuge the vessels at 2,000 rpm in the centrifuge in the clay lab
4. very carefully decant and discard the water
5. add 5 ml aqua regia (1.25 ml HNO_3 + 3.75 ml HCl)

6. add 2 ml hydrofluoric acid
7. let stand for ½ hour with caps very loose
8. microwave on high power for 5 min
9. allow to cool (in a cold water bath if desired)
10. add 40 ml of 2.5% (w/v) boric acid
11. let stand at least ½ h
12. dilute with milli-q to 100 g
13. centrifuge in the clay lab as above
14. decant into 4 oz. plastic bottle for analysis (note any remains)

II. TOTAL DIGEST

A. do as "D. RESIDUAL FRACTION" above except start with 0.2 g of sediment in the Teflon reaction vessel and add 0.2 ml milli-q to wet the sediment. Continue with step 5.

Appendix of Soil Water, Well, and Water Level, and Precipitation Data

Tensiometer readings in centibars (cb) of negative pressure.

		Site A tensiometers						Site B tensiometers			
Date	Time	15cm	30cm	46cm	87cm	120cm	141cm	15cm	30cm	60cm	108cm
5/27/94	11:00			13.0	15.0						
5/27/94	18:00			13.0	15.0						
6/1/94	9:30			13.0	15.0						
6/1/94	17:00	20.5	19.0	13.0	15.0	12.0	19.5	30.0	7.0	12.0	16.0
6/15/94	14:00	16.0	12.0			13.0	20.0	33.0	8.0	14.0	18.0
6/16/94	9:30	5.0	10.0	10.0	15.2	11.5	18.0	35.0	6.5	14.5	16.0
6/16/94	13:40	5.0	10.0			12.0	19.0	35.0	7.0	14.0	16.0
6/22/94	12:20	30.0	19.0			16.0	22.0	20.0	8.0	16.0	20.0
6/24/94	16:00	34.0	24.0			15.0	21.0	24.0	8.0	17.0	19.0
6/27/94	15:35	36.0	26.0			15.0	21.0	31.0	7.0	18.0	17.0
6/30/94	16:20	37.0	29.0			15.0	21.0	33.0	8.0	18.0	18.0
7/1/94	10:45	36.0	28.0	10.0	17.5	15.0	21.0	36.5	5.5	14.5	18.0
7/5/94	15:40	48.0	37.0			12.0	18.0	38.0	7.0	15.0	16.0
7/6/94	11:30	6.0	32.0			9.0	15.0	40.0	4.0	14.0	11.0
7/6/94	17:40	11.0	34.0			9.0	16.0	41.0	5.0	14.0	12.0
7/7/94	14:00	16.0	28.0			13.0	20.0	39.0	8.0	16.0	17.0
7/8/94	17:15	23.0	25.0			13.0	19.0	32.0	7.0	17.0	16.0
7/11/94	17:15	30.0	26.0			14.0	19.0	27.0	7.0	20.0	17.0
7/13/94	11:00	32.0	25.0			13.0	20.0	28.0	6.0	15.0	17.0
7/14/94	9:10	29.0	24.0			12.0	20.0	26.0	4.0	14.0	16.0
7/14/94	11:00	31.5	24.0	10.0	16.0	12.8	20.5	22.0	6.5	16.0	19.5
7/14/94	16:00	39.5	35.0	10.0	17.5	12.5	20.5	36.0	8.0	14.0	15.5
7/14/94	20:15	33.0	34.0			12.0	17.0	32.0	5.0	13.0	14.0
7/15/94	15:30	33.0	34.0			12.0	17.0	32.0	5.0	13.0	14.0
7/22/94	11:15	34.0	34.0			14.0	21.0	36.0	5.0	15.0	18.0
7/25/94	11:15	37.0	36.0			12.0	20.0	41.0	5.0	14.0	18.0
7/27/94	12:20	30.0	35.0			14.0	21.0	39.0	5.0	15.0	19.0
7/28/94	8:00	38.5	41.5	15.5	10.0	12.0	15.5	47.0	4.0	13.0	16.0
7/28/94	13:30	54.0	41.0	11.5	18.0	14.0	20.5	26.0	7.5	16.0	18.0
8/3/94	11:30	46.0	38.0			14.0	20.0	41.0	6.0	15.0	19.0
9/19/94	16:00	43.0	52.0	13.0	16.0	14.0	19.5	36.0	8.0	17.0	18.0

Well construction information.

Location ID	x coord	y coord	well head elev (ft)	well length (feet)	well screen (in.)	above ground length(ft)
AL32	85.3	95	aprx 5261.8			
AL48	85.3	95	aprx 5261.9			
AL85	85.3	95	aprx 5261.10			
AL125	85.3	95	aprx 5261.11			
BL32	33.5	72.5	5259.75			
BL55	33.5	72.5	5259.51			
BL87	33.5	72.5	5259.84			
BL114	33.5	72.5	5259.79			
BL130	33.5	72.5	5259.54			
P1	84.5	95	5261.83	8.67	6.00	1.00
P1B	86	95	5261.34	6.21	6.00	0.46
P23	33	73.5	5260.89	8.25	6.00	1.00
P60	34	72	5261.63	7.51	6.00	1.67
MW1	68	64.5	5261.83	8.00		
MW2	79	58.5	5261.77	8.00		
MW3	73	62	5261.13	10.00		
P3	135	73	5261.95	6.95	6.00	1.00
P4	131.5	30	5261.93	7.68	6.00	1.00
P5	416	24	5265.07	6.39	6.00	1.00
P6	393	-20	5264.38	6.70	6.00	1.00
P8	280	76	5259.67	3.28	6.00	1.00
P9	308	30	5263.68	6.88	6.00	1.00
P10	133	103	5262.04	8.58	6.00	1.00
P11	103.5	14.5	5258.62		6.00	1.00
P12	126	142.5	5262.23	8.49	6.00	1.07
P13	94	150.5	5260.20	5.72	6.00	1.21
P14	58	149.5	5261.86	7.95	6.00	0.97
P15	27	112	5260.06	8.51	6.00	1.10
P16	27.5	53.5	5258.81	5.51	6.00	1.00
P17	24	33	5258.10	7.08	6.00	1.00
P18	84	85	5261.73	8.41	6.00	1.00
P19	83	77	5261.75	7.50	6.00	1.00
P20A	85	105	5258.11	4??	6.00	1.00
P20B	105.5	127.5	?	5.94	6.00	1.00
P21	86.5	114.5	5259.89	4.52	6.00	1.00
P22	29.5	76	5257.81	3.90	6.00	1.00
P24	38	72.5	5259.70	7.05	6.00	1.00
P25	288	94	5264.40	7.60	6.00	1.00
P26	86.5	131	5257.67	2.74	6.00	1.04
P27	71	124.5	5258.80	3.91	6.00	1.11
P28	72	103	5258.32	3.96	6.00	1.17
P29	105	125	5258.61	3.06	6.00	1.00
P30	83	92.5	5262.00	20.76	6.00	1.00
P31	84.5	92	5261.96	26.11	6.00	1.00
P32	85.5	91.5	5261.89	14.19	6.00	1.00
P33	58.5	108	5261.41	10.66	6.00	1.00
P34	60	1.8	5261.49	18.14	6.00	1.00
P35	11.5	87.5	5260.63	25.12	6.00	1.00
P36	12.5	87.5	5260.61	16.86	6.00	1.06
P37	13.5	87.5	5260.45	13.71	6.00	1.00
P38	23	79	5257.44	3.97	6.00	1.16
P39	82.5	161	5262.23	8.10	6.00	0.97
P40	18	81	5259.34	8.46	6.00	0.96
P41	51	70	5260.90	8.19	6.00	1.00
P42	67.5	62	5261.79	8.58	6.00	1.00
P43	68	67	5261.74	8.79	6.00	1.00
P44	28	64	5258.82	5.28	6.00	1.00
P45	37	87	5257.62	3.97	6.00	1.00
P46	106	3	5261.73	6.59	6.00	1.00
P47	31	12	5262.10	8.97	6.00	1.00
P49	26	75	?	7.31	6.00	3.42
P50	28.5	75	?	4.55	open	3.29
P59	14	81	?	5.84	6.00	
P61	24	76	?	9.09	.5" pvc	2.58
P62	23.5	76.5	?	5.89	6.00	3.50

Water Level Elevations Measured at Wells (in meters)								
	Date							
Well ID	5/23/94	5/27/94	6/1/94	6/16/94	7/1/94	7/14/94	7/28/94	9/19/94
P1	1602.069	1602.036	1602.015	1602.057	1601.996	1601.978	1601.981	1601.932
P1B		1602.039	1602.018	1602.057	1601.996	1601.981	1601.975	1601.932
P23	1601.801	1601.753	1601.740	1601.774	1601.707	1601.689	1601.673	1601.621
P60		1601.737	1601.719	1601.756	1601.685	1601.670	1601.652	1601.597
MW1	1601.969							
MW2	1602.033							
MW3	1601.957							
P3	1602.423	1602.386						
P4	1602.454	1602.396						
P5				1603.191				
P6				1603.215				
P8				1602.548				
P9	1602.810			1602.703				
P10	1602.356	1602.332						
P11	1602.423							
P12	1602.258		1602.213					
P13	1602.170		1602.118					
P14	1602.158		1602.112					
P15	1601.725		1601.396					
P16	1601.698	1601.673						
P17	1601.597			1601.515				
P18	1602.060	1602.027					1601.935	
P19	1602.069	1602.057					1601.923	
P20A	1602.060						1601.981	
P20B								
P21	1602.106		1602.088					
P22	1601.792	1601.740					1601.670	1601.628
P24	1601.820	1601.783						
P25	1602.661			1602.621				
P26	1602.124		1602.097					
P27	1602.112		1602.073					
P28	1602.005		1601.993					
P29	1602.158		1602.140					
P30	1602.012	1601.990						
P31	1601.984	1601.966						
P32	1602.063	1602.030						
P33	1601.990		1601.890					
P34	1602.042		1601.902					
P35	1600.954		1601.512					
P36	1600.942		1601.484					
P37	1600.975		1601.542					
P38	1601.588		1601.533				1601.448	
P39	1602.198		1602.179					
P40	1601.606		1601.856					
P41	1601.902	1601.871						
P42	1601.975	1601.948					1601.832	
P43	1601.966			1601.917			1601.826	
P44	1601.792	1601.756						
P45	1601.817			1601.798				
P46	1603.194			1602.493				
P47				1601.737				

Daily Precitation Totals for the Mile Crossing - Silver Bow Creek Research Site

Data collected by the EERC, UND, Grand Forks, ND from rain gauge located at the research site.

Date	Precip (in.)	Precip (cm)
4/1/94	0	0
4/2/94	0	0
4/3/94	0.05	0.127
4/4/94	0.03	0.076
4/5/94	0.02	0.051
4/6/94	0.08	0.203
4/7/94	0.05	0.127
4/8/94	0	0
4/9/94	0	0
4/10/94	0	0
4/11/94	0	0
4/12/94	0.05	0.127
4/13/94	0	0
4/14/94	0	0
4/15/94	0	0
4/16/94	0	0
4/17/94	0	0
4/18/94	0	0
4/19/94	0	0
4/20/94	0	0
4/21/94	0.11	0.279
4/22/94	0.36	0.914
4/23/94	0.12	0.305
4/24/94	0.21	0.533
4/25/94	0.06	0.152
4/26/94	0.02	0.051
4/27/94	0	0
4/28/94	0	0
4/29/94	0	0
4/30/94	0	0
5/1/94	0.18	0.457
5/2/94	0	0
5/3/94	0	0
5/4/94	0	0
5/5/94	0.02	0.051
5/6/94	0	0
5/7/94	0	0
5/8/94	0	0
5/9/94	0	0
5/10/94	0	0
5/11/94	0	0
malfunction of instruments		
6/11/94	0.14	0.36
6/12/94	0.01	0.03
6/13/94	0.39	0.99
6/14/94	0.02	0.05
6/15/94	0.24	0.61
6/16/94	0.17	0.43
6/17/94	0.01	0.03
6/18/94	0	0.00
6/19/94	0	0.00
6/20/94	0.13	0.33
6/21/94	0.09	0.23
6/22/94	0.14	0.356

Date	Precip (in.)	Precip (cm)
6/23/94	0	0
6/24/94	0	0
6/25/94	0	0
6/26/94	0	0
6/27/94	0	0
6/28/94	0	0
6/29/94	0	0
6/30/94	0	0
7/1/94	0	0
7/2/94	0.13	0.3302
7/3/94	0	0
7/4/94	0	0
7/5/94	0.89	2.2606
7/6/94	0.78	1.9812
7/7/94	0	0
7/8/94	0	0
7/9/94	0.43	1.0922
7/10/94	0	0
7/11/94	0	0
7/12/94	0	0
7/13/94	0	0
7/14/94	0	0
7/15/94	0	0
7/16/94	0	0
7/17/94	0	0
7/18/94	0	0
7/19/94	0	0
7/20/94	0	0
7/21/94	0	0
7/22/94	0	0
7/23/94	0.11	0.2794
7/24/94	0.13	0.3302
7/25/94	0.1	0.254
7/26/94	0	0
7/27/94	0.39	0.9906
7/28/94	0.01	0.0254
7/29/94	0	0
7/30/94	0.13	0.3302
7/31/94	0	0
8/1/94	0	0
8/2/94	0	0
8/3/94	0	0
8/4/94	0.1	0.254
8/5/94	0	0
8/6/94	0	0
8/7/94	0	0
8/8/94	0	0
8/9/94	0	0
8/10/94	0	0
8/11/94	0.06	0.1524
8/12/94	0	0
8/13/94	0	0
8/14/94	0	0
8/15/94	0	0

Date	Precip (in.)	Precip (cm)
8/16/94	0	0
8/17/94	0	0
8/18/94	0	0
8/19/94	0	0
8/20/94	0	0
8/21/94	0	0
8/22/94	1.09	2.7686
8/23/94	0	0
8/24/94	0	0
8/25/94	0	0
8/26/94	0	0
8/27/94	0	0
8/28/94	0	0
8/29/94	0	0
8/30/94	0	0
8/31/94	0	0
9/1/94	0	0
9/2/94	0	0
9/3/94	0	0
9/4/94	0.61	1.5494
9/5/94	0	0
9/6/94	0	0
9/7/94	0	0
9/8/94	0	0
9/9/94	0	0
9/10/94	0.01	0.0254
9/11/94	0	0
9/12/94	0	0
9/13/94	0	0
9/14/94	0	0
9/15/94	0	0
9/16/94	0	0
9/17/94	0	0
9/18/94	0	0
9/19/94	0	0
9/20/94	0	0
9/21/94	0	0
9/22/94	0	0
9/23/94	0	0
9/24/94	0	0
9/25/94	0	0
9/26/94	0	0
9/27/94	0.63	1.6002
9/28/94	0	0
9/29/94	0	0
9/30/94	0	0
10/1/94	0	0
10/2/94	0	0
10/3/94	0	0
10/4/94	0	0
10/5/94	0	0
10/6/94	0	0
10/7/94	0	0

Appendix of Sediment Geochemistry Data

Sample depths and names for sediment cores and Core Logs

Depths are in cm below ground surface. Core depth is the actual cm measured when the core was extracted. Real depth is the "calculated depth" of the sample allowing for uniform compaction during coring. **Real depth corresponds to sample name used in analysis.** Micro column corresponds to sample names used by UMT microbiologists.

Core A 1 m NE of lysimeters at Site A. July 1, 1994. Water table = 143cm

Core depth	Real depth	Micro
AC 1-10	A 0-12	none
AC 10-19	A 12-22	A1
AC 19-26.5	A 22-31	none
AC 26.5-34.5	A 31-41	none
AC 34.5-41	A 41-48	none
AC 41-53	A 48-63	none
AC 53-80	A 63-94	A2
AC 80-107	A 94-126	A2
AC 107-120.5	A 126-142	A3
AC 120.5-128.5	A 142-152	A4
AC 128.5-141	A 152-166	none
AC 141-149	A 166-176	A5
AC 149-170	A 176-201	

Core B 0.5 m W of instruments at Site B (5-10 cm lower in elevation) July 1, 1994. Water table = 130

Core depth	Real depth	Micro
BC 0-18	B 0-21	none
BC 18-30	B 21-35	B1
BC 30-31	B 35-36	none
BC 31-62	B 36-73	B2
BC 62-76	B 73-90	B3
BC 76-94	B 90-111	B4
BC 94-114	B 111-135	none
BC 114-125	B 135-148	B5
BC 125-131	B 148-155	B6

Core C on lower bench along B transect. July 28, 1994. WT = 54cm

Core depth	Real depth	Micro
C 1-2	C 0-2	C1
C 2-12	C 2-14	C2
C 12-27	C 14-35	C3
C 30-40	C 35-47	C4
C 40-66	C 47-78	C5
C 66-68	C 78-80	none
C 68-72	C 80-85	C6
C 72-82	C 85-97	C7

Core D nr. well P43 and MW wells.
July 28, 1994. WT = 157cm

Core depth	Real depth	Micro
D 0-8	D 0-11	D1
D 8-25	D 11-35	D2
D 25-35	D 35-53	D3
D 41-70	D 53-97	D4
D 70-72	D 97-100	D5
D 100-102	D 138-141	"
D 70-130	D 100-180	"
D 130-141	D 180-195	D6
D 141-151	D 195-209	D7

Core E just N of well P19
July 28, 1994. WT = 145cm

Core depth	Real depth	Micro
E 0-10	E 0-12	E1
E 10-45	E 12-54	E2
E 45-70	E 54-84	E3
E 70-100	E 84-120	E4
E 100-130	E 120-156	E5
E 130-132	E 156-158	E6

Core F in stream on B transect closer
toW bank just N of wells P51, P49. July 28, 1994.

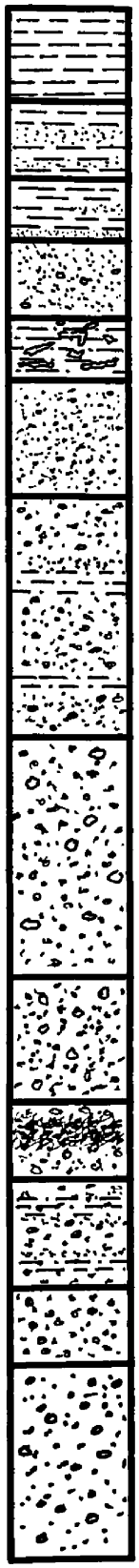
Core depth	Real depth	Micro
F 0-5	F 0-6	F1
F 5-25	F 6-30	F2
F 25-45	F 30-54	F3
F 46-62	F 54-73	F4
F 62-65	F 73-77	F5

Core G on island between channels
of creek N of Site A. July 28, 1994
WT = 25-30cm

Core depth	Real depth	Micro
G 0-8	G 0-11	G1
G 8-24	G 11-33	G2
G 24-35	G 33-48	G3
G 35-46	G 48-63	G4
G 46-56	G 63-77	G5
G 56-70	G 77-96	G6

CORE A lithologic log

Location: Approx. one meter NW of the lysimeters at Site A. Approx. 2 meters S of the stream.
Est. compaction: 15%. Depths given in cm. Approximate scale: 1 cm = 10 cm



0-12 Brownish gray surface clay, crystals of salts.

12-22 Brownish gray clay, tan to slightly orange-red fine sand.

22-31 Slightly wet dark brown clay w/ thin dry red v fine sand.

31-41 Reddish-gray fine sand. Some grains 0.5-2 cm in dia.

41-48 Dark reddish-gray clayey silt with visible organic matter (twigs, peat). Slightly wet.

48-63 Orange-red fine to medium sand.

63-94 Orange-red medium to coarse sand. Some fine sand and silt.

94-126 Orange-brown medium to coarse sand. Pebbles up to 7mm dia.

126-142 Orange-red coarse sand & pebbles. Slightly wet.

142-152 As above but with a slightly dark red-orange band at interface of vadose zone and ground water. Saturated.

152-166 Dark red-orange medium to coarse sand with gray fine sand and silt.

166-176 Well sorted dark red-orange medium to coarse sand.

176-201 Gray medium to coarse sand and pebbles.

CORE B lithologic log

Location: Approx. 0.5 m W of instrumentation at site B (5-10 cm lower in elevation)

Depths given in cm. Approximate scale: 1 cm = 10 cm

0-21 Fine sand/clay mixture. Brown/gray clay. 1 cm sand from 20-21 cm depth.

21-35 Orange-red medium to coarse poorly sorted sand.

35-36 Dark brownish gray clay with thin orange-red coatings.

36-73 Very orange-red medium to coarse sand, dry. Some tan fine sand.

73-90 Very orange-red coarse sand, dry. Some tan fine sand.

90-111 Very orange-red coarse sand, dry. With pebbles.

111-135 Very orange-red coarse sand, dry. With pebbles.

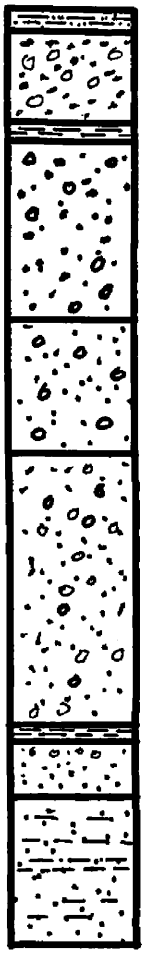
135-148 Very orange-red coarse sand, wet. With pebbles.

148-155 Very orange coarse sand, saturated. With pebbles. When dry this sample was lighter orange in color the grains had a powdery texture.

CORE C lithologic log

Location: On lower bench 1 m east of E side of creek near well P22.

Depths given in cm. Approximate scale: 1 cm = 10 cm



0-2 Fine-grained brown/gray silty sand.
2-14 Orange-red coarse pebbly sand.
1 cm clay layer, not sampled

14-35 Gray coarse, pebbly sand. No orange coatings. Slightly brown

35-47 Gray coarse, pebbly sand. No orange coatings. Slightly brown

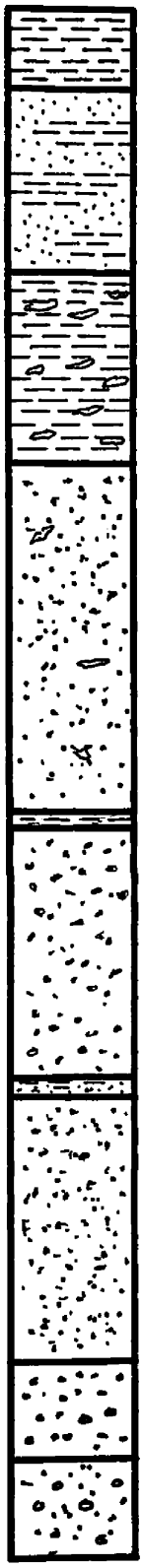
47-78 Reddish-brown and gray saturated coarse sand with pebbles.

78-80 Brown clay.
80-85 Transition zone between reddish brown and gray saturated coarse sand and dark brownish-gray sand

85-97 Saturated dark brownish-gray, muddy sand.

CORE D lithologic log

Location: Near well P43 and wells MW2, MW3, MW4. On furthest point distant from stream.
Depths given in cm. Approximate scale: 1 cm = 10 cm



0-11 Brownish gray surface clay, crystals of salts.

11-35 Dark brown clay and fine sand.

35-53 Dark gray brown clay with organic matter (grass and other plant remains)

53-97 Fine to medium dark brown sand. Lumps easily broken-up. Some organic matter but less than in above sample. Lumps slightly reddish-orange coated.

97-100 Brown-gray clay. Lumps very hard to break-up. Some reddish coatings.

100-180 Medium to fine light brown sand. Some reddish coatings.

138-141 Fine to medium gray/brown muddy sand. Lumps break easily.

100-180 Medium to fine light brown sand. Some reddish coatings.

180-195 Medium to coarse tan sand. Only a few grains in sample have reddish coatings. Sand up to 4mm in diameter.

195-209 Coarse sand as above with small pebbles.

CORE E lithologic log

Location: 0.5 m N of well P19, midway between cores D and A.

Depths given in cm. Approximate scale: 1 cm = 10 cm

0-12 Mottled gray and reddish-orange muddy sand interlayered with 1-2 cm layers of yellowish-gray mud. Muddier near top of core.

12-54 Round medium to coarse sand. Very orange-red in color

54-84 As above.

84-120 As above.

120-156 As above and wet.

156-158 Dark reddish-brown heavily coated medium sand. Water table.

CORE F lithologic log

Location: In creek on B cross-section. 1 m N of wells P51, P49, and P62.
Depths given in cm. Approximate scale: 1 cm = 10 cm

0-6 Medium to coarse reddish-gray sand.

6-30 Very coarse to pebbly reddish-gray sand.

30-54 Sandy pebbles with intermixed layers of medium to coarse sand. Reddish-brown in color. Possibly oxic.

54-73 Medium to coarse sand with minor pebbles and some mud. Transition from reddish to grayish in upper 5cm of sample. Grayish-brown in color below. Possibly reduced.

73-77 Black muddy sand with organic matter "roots?".

CORE G lithologic log

Location: On island in creek near well P20A and N of Site A.

Depths given in cm. Approximate scale: 1 cm = 10 cm

0-11 Grayish brown muddy sand. Oxic zone. Water table at 8 cm.

11-33 Black sulfidic mud and muddy sand with black decomposed sticks, roots, and possibly algae. Black sand at lower 3 cm.

33-48 Grayish-brown medium to coarse sand. Possible transition zone between reduced sulfidic zone above and oxic zone below.

48-63 Reddish-brown medium to coarse sand with pebbles. Probable oxic zone.

63-77 Brownish-gray medium to coarse pebbly sand. Muddy. Possible transition zone from oxic environment above to reduced environment.

77-96 Brownish-gray coarse pebbly sand.

SEDIMENT GEOCHEMISTRY as ug metal/g sed (C as %C)

Sample*	Al**	As	Ca	Cd	Co	Cu	Fe	Mg	Mn	Mo	Na	Ni	Pb	Si	Sr	Ti	Zn	%C
A 000-012 1W	37	BIDL	1234.8	8.21	0.65	543.0	6.2	276.1	1469.1	BIDL	340.9	BIDL	BIDL	81	2.66	BIDL	1988.6	
A 000-012 2R	1655	374.7	930.7	9.25	BIDL	1725.4	8227.3	99.2	1024.8	13.4	46.8	BIDL	137.0	418	7.35	BIDL	1159.8	
A 000-012 3O	7191	292.0	699.3	12.55	4.59	955.5	16103.0	2974.3	757.9	33.7	110.0	4.83	1593.8	2428	28.21	738.5	3321.0	
A 000-012 4Z	61297	BIDL	9323.4	BIDL	5.57	61.5	18336.8	5576.1	1106.4	28.0	8840.0	5.85	158.6	235732	158.83	1775.3	335.7	
A 000-012 5T	65392	698.2	11308.3	30.04	12.39	3356.6	40120.0	8505.8	4178.7	69.4	9440.0	BIDL	1701.2	233050	192.05	2329.0	6617.8	1.81
A 012-022 1W	10	BIDL	102.7	1.35	BIDL	119.9	5.8	35.5	257.3	BIDL	36.7	BIDL	BIDL	63	1.12	BIDL	368.7	
A 012-022 2R	1428	206.5	493.5	4.46	BIDL	852.5	7892.9	39.7	716.0	13.0	BIDL	BIDL	111.3	293	4.26	BIDL	630.7	
A 012-022 3O	5605	159.8	687.9	10.67	4.31	496.5	13709.6	2928.5	638.9	29.6	44.5	4.03	894.6	2325	12.60	747.1	3379.1	
A 012-022 4Z	60314	BIDL	13511.3	BIDL	4.73	41.1	14746.6	5331.0	961.8	22.9	11407.3	7.12	113.0	214719	221.56	1362.0	229.8	
A 012-022 5T	66980	409.8	14036.3	16.99	12.31	1589.3	36642.2	8520.3	2643.3	63.2	12657.3	BIDL	1088.4	271861	242.36	2220.7	4900.4	1.35
A 022-031 1W	25	BIDL	169.8	2.42	BIDL	209.0	14.9	42.4	466.7	BIDL	30.0	BIDL	BIDL	117	1.24	BIDL	611.1	
A 022-031 2R	1484	293.1	440.5	7.17	BIDL	1117.6	10978.3	44.6	627.5	17.8	BIDL	BIDL	120.8	508	5.41	BIDL	770.6	
A 022-031 3O	6864	214.1	631.2	10.32	4.27	622.1	14901.2	2945.2	337.1	31.2	38.4	4.78	884.9	2489	15.76	707.1	2699.1	
A 022-031 4Z	59114	BIDL	6703.3	BIDL	4.68	45.5	16333.4	5288.6	580.1	25.0	6570.2	9.34	162.7	219421	125.45	1617.2	201.8	
A 022-031 5T	64411	545.0	7233.8	18.98	10.85	2031.9	40628.4	7977.0	1910.0	69.0	7184.3	BIDL	1075.2	266066	148.00	2251.4	4230.8	1.88
A 031-041 1W	3	BIDL	46.1	0.64	BIDL	57.8	1.7	13.9	127.5	BIDL	BIDL	BIDL	BIDL	48	0.39	BIDL	165.2	
A 031-041 2R	622	187.2	746.4	2.65	BIDL	378.4	7061.7	50.6	397.7	13.5	BIDL	BIDL	251.1	296	7.07	BIDL	365.6	
A 031-041 3O	1836	67.8	89.7	6.29	2.13	177.5	8055.9	1204.4	217.4	15.5	75.5	BIDL	314.6	1631	10.96	316.0	2114.2	
A 031-041 4Z	47343	BIDL	7628.4	BIDL	1.82	15.9	7622.5	3595.7	471.5	12.4	7161.9	BIDL	205.4	211029	142.60	707.7	116.7	
A 031-041 5T	49475	244.9	7200.8	10.78	5.39	617.2	21896.4	4403.8	1189.4	36.5	7494.8	BIDL	744.6	204759	162.34	1047.8	3330.5	0.30
A 041-048 1W	11	BIDL	103.9	1.48	BIDL	157.5	1.7	29.1	299.5	BIDL	31.4	BIDL	BIDL	83	0.82	BIDL	386.4	
A 041-048 2R	571	226.5	440.0	4.89	BIDL	755.2	8049.7	37.2	415.4	13.1	BIDL	BIDL	260.4	317	6.65	BIDL	515.4	
A 041-048 3O	4218	192.2	348.5	8.75	3.54	515.6	11744.0	2273.4	199.0	25.2	BIDL	3.74	1132.6	2663	13.39	610.3	2200.5	
A 041-048 4Z	53636	BIDL	6509.1	BIDL	4.00	26.7	13087.9	4525.5	560.6	20.3	5760.7	7.30	193.5	220257	124.28	1328.3	171.8	
A 041-048 5T	56018	434.6	6402.1	13.45	9.40	1521.0	30710.1	6552.2	1385.0	52.7	6802.2	BIDL	1495.5	226074	141.15	1816.6	3188.0	1.88
A 048-063 1W	5	BIDL	52.0	0.63	BIDL	58.1	4.7	15.0	122.8	BIDL	BIDL	BIDL	BIDL	61	0.46	BIDL	172.7	
A 048-063 2R	640	129.9	641.5	2.42	BIDL	280.8	5465.4	34.6	359.8	11.6	BIDL	BIDL	160.6	209	3.97	BIDL	250.5	
A 048-063 3O	1647	93.3	86.6	5.76	1.89	160.5	8379.1	1041.1	214.8	17.8	60.3	BIDL	304.0	1685	10.49	283.1	1922.0	
A 048-063 4Z	44001	BIDL	6446.6	BIDL	BIDL	14.7	6440.3	3055.5	395.8	11.5	6459.0	BIDL	200.1	215860	132.23	591.6	96.0	
A 048-063 5T	47008	206.3	6828.5	7.87	BIDL	461.2	19050.5	3844.7	1027.2	34.6	6482.1	BIDL	549.2	301344	151.12	950.5	2499.8	0.37

SEDIMENT GEOCHEMISTRY as ug metal/g sed (C as %C)

Sample*	Al**	As	Ca	Cd	Co	Cu	Fe	Mg	Mn	Mo	Na	Ni	Pb	Si	Sr	Ti	Zn	%C
A 063-094 1W	23	BIDL	90.6	0.52	32.66	69.0	24.1	34.1	88.2	BIDL	40.3	BIDL	BIDL	99	1.42	BIDL	172.0	
A 063-094 2R	674	279.0	567.7	2.75	9.02	133.4	9732.8	58.1	379.4	17.3	44.1	BIDL	182.2	409	3.55	2.2	172.1	
A 063-094 3O	1266	BIDL	159.2	7.66	3.00	226.5	9181.9	738.8	191.7	16.8	119.7	BIDL	385.8	1448	7.23	240.3	1930.1	
A 063-094 4Z	52801	BIDL	11769.6	BIDL	BIDL	BIDL	7454.4	2144.7	460.3	12.2	12220.1	BIDL	121.5	245262	241.05	721.5	56.8	
A 063-094 5T	53681	47.8	11130.1	11.57	44.37	419.8	24968.9	2644.6	1100.2	41.9	12115.1	BIDL	610.7	317651	251.61	1046.0	2514.6	0.09
A 094-126 1W	8	BIDL	40.2	BIDL	BIDL	82.9	8.1	12.5	49.2	BIDL	30.6	BIDL	BIDL	75	1.34	BIDL	49.0	
A 094-126 2R	612	113.8	308.9	1.58	BIDL	293.1	5446.6	13.8	950.1	8.8	BIDL	BIDL	199.4	323	3.05	BIDL	130.2	
A 094-126 3O	1537	162.3	231.2	7.66	1.53	508.7	8452.0	690.3	140.0	13.9	38.6	BIDL	138.7	1832	3.87	166.1	1672.6	
A 094-126 4Z	57676	BIDL	10793.5	BIDL	BIDL	BIDL	5065.3	1342.6	317.5	8.6	11946.2	BIDL	71.5	222672	266.94	449.3	46.3	
A 094-126 5T	60267	306.6	10751.6	7.67	4.48	919.4	19189.0	2160.0	1620.0	30.4	13644.4	BIDL	481.7	303745	285.28	729.0	1825.4	0.11
A 126-142 1W	5	BIDL	86.6	BIDL	BIDL	9.4	7.4	23.6	15.0	BIDL	35.0	BIDL	BIDL	91	1.14	BIDL	23.4	
A 126-142 2R	490	101.7	351.4	1.39	BIDL	97.7	7210.2	21.7	258.7	11.0	BIDL	BIDL	180.0	367	2.55	BIDL	146.0	
A 126-142 3O	1653	199.4	197.9	11.01	1.87	250.0	10678.0	942.5	243.6	18.6	BIDL	BIDL	424.2	1961	3.69	255.0	2929.9	
A 126-142 4Z	61060	BIDL	13159.3	BIDL	BIDL	8.8	6534.1	1789.4	473.9	10.4	14263.7	BIDL	65.1	221204	296.64	587.6	70.3	
A 126-142 5T	56844	128.7	11084.1	9.24	BIDL	320.3	22469.2	2717.0	834.9	38.1	13544.2	BIDL	682.4	237806	265.53	850.2	2410.3	0.20
A 142-152 1W	65	BIDL	100.0	BIDL	BIDL	10.4	97.9	25.3	9.9	BIDL	45.8	BIDL	BIDL	265	0.85	0.8	18.0	
A 142-152 2R	1146	68.8	824.5	3.31	BIDL	1690.9	14986.5	84.9	783.1	24.2	BIDL	BIDL	574.2	1360	6.45	BIDL	690.3	
A 142-152 3O	1635	272.5	207.3	10.87	2.22	1026.7	13721.4	903.0	246.4	22.8	68.0	2.63	159.1	1499	4.16	243.4	2772.6	
A 142-152 4Z	55386	BIDL	11243.8	BIDL	BIDL	BIDL	4318.8	1760.8	379.9	7.3	14075.6	BIDL	86.9	235792	252.91	472.2	68.8	
A 142-152 5T	60416	360.5	11881.8	13.44	BIDL	2532.4	30308.7	2733.8	1357.9	46.5	14600.6	BIDL	699.8	308625	278.22	830.2	3659.7	0.20
A 152-166 1W	34	BIDL	122.7	BIDL	BIDL	27.6	65.7	27.7	11.0	BIDL	38.7	BIDL	4.1	173	1.09	BIDL	31.3	
A 152-166 2R	909	70.5	808.5	2.22	BIDL	1429.1	7333.2	70.7	499.3	12.1	BIDL	BIDL	512.3	744	5.60	BIDL	516.2	
A 152-166 3O	1486	430.6	160.6	16.42	2.69	2120.8	9532.6	787.0	236.4	15.0	39.9	3.20	105.6	1530	2.83	215.2	3775.4	
A 152-166 4Z	50522	BIDL	9521.7	BIDL	BIDL	24.0	5590.4	1636.5	505.8	8.9	12045.5	BIDL	71.1	186421	232.61	469.9	104.6	
A 152-166 5T	56850	497.4	10659.4	18.05	4.45	3763.9	21697.8	2638.8	1240.8	32.8	13975.6	BIDL	620.6	253930	262.88	795.4	4520.5	0.11
A 166-176 1W	44	BIDL	68.2	BIDL	BIDL	24.8	131.8	16.7	13.4	BIDL	38.3	BIDL	9.5	192	0.63	BIDL	11.4	
A 166-176 2R	729	67.0	775.2	1.90	BIDL	1139.6	7808.5	75.2	661.1	12.4	BIDL	BIDL	530.2	803	6.91	BIDL	459.3	
A 166-176 3O	1194	325.2	194.4	12.09	1.61	1746.9	8412.6	602.3	270.5	13.0	38.6	BIDL	91.7	1406	2.78	156.9	2753.7	
A 166-176 4Z	47735	BIDL	9164.1	BIDL	BIDL	9.1	3694.0	1397.2	504.7	6.4	11089.2	BIDL	91.9	186458	218.08	393.9	78.8	
A 166-176 5T	55062	389.4	10161.5	12.51	5.26	3046.5	19271.8	2342.7	1386.6	28.7	12664.4	BIDL	700.8	264800	253.04	752.9	3232.7	0.09

SEDIMENT GEOCHEMISTRY as ug metal/g sed (C as %C)

Sample*	Al**	As	Ca	Cd	Co	Cu	Fe	Mg	Mn	Mo	Na	Ni	Pb	Si	Sr	Ti	Zn	%C
A 176-201 1W	137	BIDL	98.0	BIDL	BIDL	BIDL	133.7	42.3	14.5	BIDL	73.9	BIDL	BIDL	479	0.85	4.4	7.0	
A 176-201 2R	374	BIDL	1367.4	BIDL	1.48	29.4	874.0	140.8	138.1	BIDL	47.6	BIDL	21.3	234	11.89	BIDL	153.3	
A 176-201 3O	1388	BIDL	282.0	BIDL	2.84	37.5	5814.0	723.2	38.3	8.4	65.5	BIDL	10.5	1799	6.52	164.8	78.2	
A 176-201 4Z	68975	BIDL	15380.1	BIDL	2.21	BIDL	13251.3	1814.9	122.7	19.4	18524.9	BIDL	66.2	215881	377.22	1022.2	BIDL	
A 176-201 5T	76716	36.6	17629.5	BIDL	8.59	38.4	22049.6	2916.2	366.2	29.5	21236.7	BIDL	56.4	258092	437.28	1494.7	266.1	0.10
B 000-021 1W	49	BIDL	683.1	2.40	0.45	522.3	29.3	159.0	346.3	BIDL	195.6	BIDL	BIDL	153	2.71	BIDL	593.6	
B 000-021 2R	3053	344.4	1160.8	7.99	1.25	2370.2	18100.2	190.7	564.1	31.0	BIDL	BIDL	366.9	893	7.80	BIDL	884.6	
B 000-021 3O	9472	245.8	820.3	6.20	5.70	691.0	18886.2	3795.7	274.4	37.3	47.0	5.90	635.1	2179	17.01	841.2	1367.4	
B 000-021 4Z	60512	BIDL	6245.9	BIDL	5.22	50.5	18589.8	5735.0	376.5	28.5	7265.4	6.75	123.4	203072	116.84	1891.4	203.9	
B 000-021 5T	77934	586.9	8851.8	15.25	14.87	3442.1	53880.6	10343.2	1534.2	90.7	8515.1	13.95	1063.2	242944	159.14	3014.4	3035.6	2.19
B 021-035 1W	18	BIDL	114.8	0.52	BIDL	124.1	15.6	31.0	78.5	BIDL	17.4	BIDL	BIDL	98	1.22	BIDL	133.3	
B 021-035 2R	1388	111.1	443.2	1.88	BIDL	433.1	13789.2	46.1	657.0	23.0	BIDL	BIDL	263.8	808	3.68	2.1	225.9	
B 021-035 3O	1987	175.7	354.2	6.98	2.33	392.6	10884.8	1182.3	149.7	20.3	46.3	BIDL	175.8	1667	4.91	306.8	1815.9	
B 021-035 4Z	54264	BIDL	9552.2	BIDL	BIDL	13.6	5406.6	2015.4	263.5	9.0	12198.6	BIDL	96.4	223643	224.75	559.2	71.8	
B 021-035 5T	58852	293.3	9435.7	8.56	5.74	944.5	25729.3	3025.3	1003.4	41.1	13278.1	BIDL	424.6	234434	240.37	914.4	2071.5	0.45
B 035-036 1W	42	BIDL	334.4	1.28	BIDL	274.9	13.7	63.5	149.7	BIDL	22.1	BIDL	BIDL	99	1.42	BIDL	387.9	
B 035-036 2R	1367	355.8	742.1	5.22	BIDL	511.5	11695.4	60.3	115.3	23.8	BIDL	BIDL	232.8	400	6.24	BIDL	221.3	
B 035-036 3O	3724	231.6	157.7	5.78	3.32	371.3	11370.5	2009.3	129.4	27.0	40.5	2.82	946.9	2021	18.06	500.9	1236.7	
B 035-036 4Z	62126	BIDL	5684.6	BIDL	2.37	28.6	9833.4	4565.8	366.8	16.2	6626.8	BIDL	334.5	239253	135.14	1088.3	164.6	
B 035-036 5T	65658	549.6	6419.9	11.62	7.59	1137.1	30640.6	6274.0	725.2	58.6	6128.1	BIDL	1434.8	250475	167.06	1676.5	2096.7	1.06
B 036-073 1W	38	BIDL	95.3	BIDL	BIDL	72.2	10.2	25.6	50.5	BIDL	24.2	BIDL	BIDL	66	1.22	BIDL	82.7	
B 036-073 2R	683	194.5	528.8	1.81	BIDL	147.1	8975.7	32.0	287.2	16.1	BIDL	BIDL	176.2	415	2.76	BIDL	137.3	
B 036-073 3O	1478	96.8	126.0	6.28	1.95	134.4	8394.6	976.0	161.2	15.6	51.5	BIDL	236.9	1608	5.05	276.9	1888.1	
B 036-073 4Z	51624	BIDL	9479.0	BIDL	BIDL	9.2	5840.7	2245.4	449.3	10.0	10408.7	BIDL	159.9	235378	208.42	535.6	60.5	
B 036-073 5T	51717	273.7	8335.0	7.63	BIDL	333.1	21138.9	2897.2	817.9	33.2	10293.3	BIDL	489.6	251557	211.09	855.6	2210.8	0.68
B 073-090 1W	61	BIDL	121.9	0.47	BIDL	86.4	15.7	37.7	66.5	BIDL	35.4	BIDL	BIDL	71	1.44	BIDL	115.0	
B 073-090 2R	594	105.8	519.1	1.02	BIDL	115.0	10321.9	30.2	230.4	16.7	BIDL	BIDL	132.6	420	2.94	BIDL	99.8	
B 073-090 3O	1171	227.6	294.2	7.18	1.48	403.8	7843.0	706.8	87.9	13.4	65.4	BIDL	179.3	1491	5.46	192.7	1264.9	
B 073-090 4Z	62356	BIDL	11520.3	BIDL	BIDL	BIDL	5432.5	1780.5	300.7	9.3	13880.3	BIDL	130.3	252779	300.53	659.3	34.2	
B 073-090 5T	60940	373.1	10453.9	10.35	5.20	676.3	22840.0	2289.0	676.3	35.0	13476.1	BIDL	424.6	254164	290.28	885.4	2044.2	0.24

SEDIMENT GEOCHEMISTRY as ug metal/g sed (C as %C)

Sample*	Al**	As	Ca	Cd	Co	Cu	Fe	Mg	Mn	Mo	Na	Ni	Pb	Si	Sr	Ti	Zn	%C
B 090-111 1W	54	BIDL	90.2	BIDL	BIDL	28.3	44.8	33.4	28.0	BIDL	48.2	BIDL	BIDL	107	1.46	BIDL	64.3	
B 090-111 2R	485	99.1	418.2	1.47	BIDL	60.7	9487.0	41.9	56.8	15.4	36.2	BIDL	115.6	303	2.70	BIDL	57.3	
B 090-111 3O	1057	142.2	177.4	3.42	1.32	142.7	6493.3	596.4	59.3	11.0	84.7	BIDL	179.1	1436	4.78	196.6	502.9	
B 090-111 4Z	54019	BIDL	11440.6	BIDL	BIDL	BIDL	3520.2	1127.4	152.4	6.1	12608.6	BIDL	63.8	197979	243.86	1139.3	27.7	
B 090-111 5T	64813	286.0	13506.7	4.60	5.15	234.3	19394.3	2023.5	336.1	29.1	15040.5	BIDL	338.9	267166	304.72	1791.0	718.4	0.09
B 111-135 1W	39	BIDL	87.5	BIDL	BIDL	18.6	40.6	25.9	29.3	BIDL	48.8	BIDL	BIDL	87	1.76	BIDL	36.8	
B 111-135 2R	374	59.5	389.9	BIDL	BIDL	54.3	9136.7	21.1	49.4	14.1	35.1	BIDL	128.1	260	2.57	BIDL	51.5	
B 111-135 3O	953	237.6	104.5	6.67	1.10	276.1	9311.8	566.3	64.7	15.0	83.1	BIDL	280.5	1460	5.19	188.8	1150.0	
B 111-135 4Z	52561	BIDL	9449.4	BIDL	BIDL	BIDL	4575.6	1200.2	138.9	7.8	11715.4	BIDL	76.3	204558	244.99	515.0	48.6	
B 111-135 5T	58984	355.4	10104.3	6.72	BIDL	369.1	23132.2	1918.3	296.5	34.9	13438.2	BIDL	457.5	268764	285.07	841.7	1319.2	0.25
B 135-148 1W	35	BIDL	81.7	BIDL	BIDL	12.4	53.8	22.7	30.8	BIDL	45.8	BIDL	BIDL	88	1.93	BIDL	33.4	
B 135-148 2R	355	29.9	368.6	BIDL	BIDL	44.6	11153.2	10.5	129.9	16.4	BIDL	BIDL	93.8	309	2.18	2.0	52.5	
B 135-148 3O	751	385.5	109.2	11.40	0.98	408.4	12583.8	384.2	89.5	20.6	88.0	BIDL	205.2	1183	4.61	133.8	1899.8	
B 135-148 4Z	48335	BIDL	9823.3	BIDL	BIDL	BIDL	4912.4	1233.4	186.6	7.3	10869.5	BIDL	92.5	198443	206.29	449.0	35.7	0.05
B 148-155 1W	20	BIDL	111.3	BIDL	BIDL	6.1	59.9	29.7	23.1	BIDL	53.4	BIDL	BIDL	82	1.46	BIDL	39.1	
B 148-155 2R	365	19.0	479.4	BIDL	BIDL	44.3	10396.0	18.2	82.3	15.3	BIDL	BIDL	63.2	291	2.69	BIDL	74.5	
B 148-155 3O	909	378.7	130.3	39.37	1.15	510.1	11976.3	515.9	89.9	19.3	64.2	BIDL	174.6	1269	2.95	162.7	5387.4	
B 148-155 4Z	45996	BIDL	9036.5	BIDL	BIDL	BIDL	4857.5	1554.2	476.1	7.8	10557.4	BIDL	136.0	192458	191.46	624.9	114.1	
B 148-155 5T	54116	479.0	10165.7	43.85	4.86	615.5	27917.8	2286.0	717.7	42.3	11986.5	1.52	396.0	233660	236.04	966.5	6337.1	0.08
C 000-002 1W	188	BIDL	7333.5	1.11	40.21	157.9	85.2	178.5	191.7	BIDL	164.5	BIDL	BIDL	210	5.20	BIDL	225.7	
C 000-002 2R	1330	165.6	1580.8	1.79	6.61	225.1	8515.6	100.8	182.0	15.1	140.3	BIDL	104.9	480	10.67	BIDL	112.0	
C 000-002 3O	3124	BIDL	201.8	3.49	4.60	230.6	14368.6	1669.9	183.3	26.8	279.9	BIDL	367.8	1743	20.82	504.3	905.4	
C 000-002 4Z	63909	BIDL	11057.5	BIDL	3.14	19.6	11158.8	3235.8	394.8	18.2	13550.5	BIDL	100.2	260745	267.63	1414.9	109.3	
C 000-002 5T	64390	BIDL	18499.5	6.79	51.97	602.5	32546.6	5179.2	889.4	56.7	13143.8	BIDL	604.4	276079	277.03	1916.3	1372.3	0.67
C 002-014 1W	11	BIDL	191.5	BIDL	33.36	7.6	28.3	28.7	38.9	BIDL	73.4	BIDL	BIDL	122	1.58	BIDL	16.1	
C 002-014 2R	582	37.3	640.0	BIDL	22.36	32.0	4867.0	42.6	523.2	8.6	78.9	BIDL	31.4	261	5.28	BIDL	37.8	
C 002-014 3O	1012	BIDL	144.1	1.01	2.88	66.9	9154.7	493.0	52.6	19.1	195.8	BIDL	72.1	1254	7.81	159.9	242.6	
C 002-014 4Z	77075	BIDL	12084.1	BIDL	2.42	BIDL	9862.5	1776.6	151.8	16.7	19125.4	BIDL	65.1	306890	420.01	1084.1	31.6	
C 002-014 5T	69630	BIDL	12059.4	BIDL	55.02	103.6	23381.0	2328.0	616.8	42.5	17087.5	BIDL	197.0	292891	361.42	1200.2	368.9	0.12
C 014-035 1W	4	BIDL	45.0	BIDL	23.34	2.2	20.0	15.0	6.4	BIDL	70.0	BIDL	BIDL	103	0.94	BIDL	6.8	

SEDIMENT GEOCHEMISTRY as ug metal/g sed (C as %C)

Sample*	Al**	As	Ca	Cd	Co	Cu	Fe	Mg	Mn	Mo	Na	Ni	Pb	Si	Sr	Tl	Zn	%C
C 014-035 2R	470	9.9	399.8	BIDL	33.55	24.6	2343.9	40.0	16.3	4.3	79.2	BIDL	26.3	170	4.54	BIDL	20.2	
C 014-035 3O	822	BIDL	132.6	1.65	3.01	130.0	12691.7	368.2	36.4	21.7	190.5	BIDL	108.3	1118	7.75	166.4	397.9	
C 014-035 4Z	77787	BIDL	11958.2	BIDL	2.82	BIDL	15764.7	1890.3	200.1	24.7	18792.2	BIDL	75.2	257572	373.28	1272.3	25.4	
C 014-035 5T	69390	BIDL	11328.0	BIDL	55.96	162.3	30691.7	2241.2	231.9	48.9	16782.4	BIDL	243.6	282521	320.41	1354.7	516.8	0.08
C 035-047 1W	18	BIDL	122.5	BIDL	40.85	6.8	66.5	44.4	16.2	BIDL	84.0	BIDL	BIDL	143	2.24	BIDL	17.4	
C 035-047 2R	730	67.1	915.9	BIDL	13.31	26.2	5862.2	60.2	18.0	9.9	49.4	BIDL	25.4	277	4.81	BIDL	27.8	
C 035-047 3O	1272	BIDL	154.7	1.98	7.97	141.4	53225.1	637.2	79.8	80.0	138.1	3.88	103.1	1265	6.64	209.3	365.7	
C 035-047 4Z	62956	BIDL	9201.0	BIDL	4.11	BIDL	30337.5	1848.5	208.6	45.0	13280.0	BIDL	76.1	259623	298.06	1367.5	19.2	
C 035-047 5T	58770	BIDL	9441.7	BIDL	61.71	174.0	93918.1	2581.0	308.1	140.8	12245.8	BIDL	226.7	266769	268.20	1532.9	479.9	0.11
C 047-078 1W	20	BIDL	90.1	BIDL	31.75	28.9	117.3	27.3	32.6	BIDL	56.7	BIDL	BIDL	88	1.67	BIDL	25.5	
C 047-078 2R	737	65.5	557.0	BIDL	6.74	63.6	7751.0	31.2	197.2	12.5	BIDL	BIDL	72.1	268	3.37	BIDL	51.1	
C 047-078 3O	1002	BIDL	158.1	7.77	2.77	638.2	12615.6	472.1	73.6	20.0	77.5	BIDL	101.7	1394	5.22	133.1	1953.8	
C 047-078 4Z	63801	BIDL	11410.0	BIDL	BIDL	BIDL	5220.4	1462.6	284.6	9.2	15428.9	BIDL	76.5	252095	326.73	700.0	25.4	
C 047-078 5T	60066	BIDL	11180.4	10.27	37.82	800.0	25049.3	1992.7	542.6	40.9	14147.9	BIDL	266.6	276587	291.35	842.8	2302.6	0.13
C 078-080 1W	4	BIDL	95.9	BIDL	28.06	608.1	5.6	32.8	21.3	BIDL	48.8	BIDL	11.8	134	1.61	BIDL	37.3	
C 078-080 2R	2159	63.4	806.9	1.17	34.66	3508.9	5828.8	91.5	167.6	10.8	BIDL	BIDL	541.5	572	6.47	BIDL	107.9	
C 078-080 3O	2727	BIDL	168.8	19.96	5.45	8285.2	12406.6	1148.2	110.4	23.7	68.5	2.76	287.0	1849	10.51	293.6	5123.0	
C 078-080 4Z	49565	BIDL	6514.3	BIDL	BIDL	12.2	5097.5	2634.7	459.1	9.4	8340.3	BIDL	152.0	292005	168.01	740.4	105.7	
C 078-080 5T	54180	BIDL	6993.9	21.69	55.32	11845.5	21954.8	3798.0	687.0	39.3	8246.4	BIDL	886.7	320726	184.19	1086.0	5325.4	0.53
C 080-085 1W	16	BIDL	80.8	BIDL	26.08	240.7	56.0	23.4	45.0	BIDL	45.6	BIDL	BIDL	127	1.48	BIDL	31.8	
C 080-085 2R	2945	55.3	620.7	BIDL	8.19	1049.4	8705.8	35.4	234.8	19.6	BIDL	BIDL	141.5	1053	4.23	BIDL	136.9	
C 080-085 3O	1571	14.8	227.4	13.57	2.74	2225.5	11610.4	637.2	125.8	19.7	57.1	BIDL	159.2	1376	5.21	176.7	3675.8	
C 080-085 4Z	60261	BIDL	10770.4	BIDL	BIDL	15.8	5707.3	1901.5	421.1	9.9	14047.3	BIDL	81.8	244771	291.14	717.9	66.3	
C 080-085 5T	60001	BIDL	10920.0	17.61	35.49	3666.5	24475.9	2656.0	757.0	46.1	13089.8	BIDL	418.8	289696	264.07	923.8	4355.6	0.17
C 085-097 1W	8	BIDL	64.8	BIDL	17.66	203.2	9.8	19.3	25.4	BIDL	49.7	BIDL	BIDL	134	1.36	BIDL	23.0	
C 085-097 2R	2799	23.7	618.6	BIDL	11.58	1573.6	3067.2	36.9	206.4	9.4	BIDL	BIDL	99.6	1098	4.78	BIDL	135.9	
C 085-097 3O	1442	BIDL	111.2	8.78	1.80	2268.7	7900.2	577.0	97.7	13.0	44.9	BIDL	70.5	1311	4.38	157.6	2342.3	
C 085-097 4Z	61148	BIDL	9956.4	BIDL	BIDL	27.0	4504.7	1635.8	465.3	8.4	14221.3	BIDL	84.5	238376	308.12	551.2	79.2	
C 085-097 5T	59727	BIDL	9947.6	11.56	28.07	3950.5	15209.9	2386.9	635.6	29.1	13091.0	BIDL	307.8	283439	277.41	756.6	2969.4	0.36
D 000-011 1W	35	BIDL	18796.2	5.76	14.54	274.1	11.6	476.7	459.7	BIDL	340.2	BIDL	BIDL	270	30.74	0.9	938.3	

SEDIMENT GEOCHEMISTRY as ug metal/g sed (C as %C)

Sample*	Al**	As	Ca	Cd	Co	Cu	Fe	Mg	Mn	Mo	Na	Ni	Pb	Sl	Sr	Tl	Zn	%C
D 000-011 2R	2377	467.5	3644.7	8.60	5.14	1719.7	16052.4	146.0	671.2	29.6	50.5	BIDL	306.9	826	17.62	2.3	566.8	
D 000-011 3O	5790	202.9	650.9	8.65	4.22	618.6	14797.4	2402.2	464.0	29.7	72.6	3.88	1084.8	2000	31.86	632.0	2411.4	
D 000-011 4Z	57616	BIDL	4824.3	BIDL	3.13	44.6	13229.9	4632.8	537.0	21.0	6101.5	4.62	212.9	234729	115.60	1385.0	215.7	1.48
D 011-025 1W	6	BIDL	829.9	1.31	0.93	85.5	5.1	83.7	144.8	BIDL	74.7	BIDL	BIDL	266	3.21	BIDL	162.0	
D 011-032 2R	1503	664.4	1359.0	18.60	29.90	5073.6	13140.9	138.2	14192.2	28.2	BIDL	BIDL	1606.3	972	10.87	2.5	1242.6	
D 011-035 3O	3472	BIDL	811.9	14.37	4.53	408.0	10374.0	1843.5	855.0	20.4	BIDL	3.00	252.2	1824	10.98	491.7	5210.8	
D 011-035 4Z	46214	BIDL	6425.0	BIDL	2.03	22.0	9243.2	4123.2	1009.6	15.4	6733.5	BIDL	137.4	270430	128.76	996.5	214.0	0.80
D 035-053 1W	16	10.0	835.2	0.42	0.46	20.5	28.0	114.9	52.3	BIDL	127.1	BIDL	31.6	378	4.36	BIDL	22.5	
D 035-053 2R	1663	1154.0	6311.7	43.03	23.15	9300.1	8924.2	541.4	14333.3	17.0	170.3	BIDL	9246.5	2283	34.31	2.6	7808.1	
D 035-053 3O	4728	130.5	1057.5	14.25	5.95	1264.5	21046.8	2455.1	5872.1	48.7	127.6	4.77	1322.7	1851	14.96	614.8	7929.8	
D 035-053 4Z	46754	BIDL	5636.7	2.18	2.71	46.7	12375.3	3715.9	7685.9	20.6	8374.8	BIDL	517.4	246555	131.65	1078.9	1670.6	1.57
D 053-097 1W	90	BIDL	261.5	BIDL	1.31	BIDL	103.9	80.3	24.6	BIDL	135.9	BIDL	BIDL	614	1.68	3.5	BIDL	
D 053-097 2R	955	BIDL	3231.6	BIDL	24.17	4.9	3343.4	456.2	400.3	5.3	80.5	BIDL	15.3	719	28.66	BIDL	20.6	
D 053-097 3O	4072	BIDL	581.0	BIDL	6.21	13.7	6589.9	2222.1	103.8	10.3	73.3	3.70	11.0	2011	16.15	639.0	39.2	
D 053-097 4Z	75931	BIDL	18979.4	BIDL	5.31	BIDL	15532.5	5145.6	261.3	23.8	22330.6	6.51	60.0	262449	415.05	1761.4	43.8	0.74
D 097-100 1W	29	BIDL	268.8	BIDL	0.76	BIDL	41.8	71.7	32.4	BIDL	140.2	BIDL	BIDL	413	1.57	BIDL	BIDL	
D 097-100 2R	953	BIDL	3791.0	BIDL	15.69	BIDL	3518.1	569.3	432.0	7.2	74.2	BIDL	15.5	804	30.87	BIDL	27.0	
D 097-100 3O	5079	BIDL	809.8	BIDL	6.63	17.6	7909.7	2725.0	132.0	12.9	62.0	4.73	14.2	2186	16.74	766.7	55.6	
D 097-100 4Z	72506	BIDL	16159.5	BIDL	5.94	BIDL	18952.8	5775.8	274.9	28.5	18750.0	6.24	58.7	267719	329.67	2000.8	69.2	1.21
D 100-180 1W	39	BIDL	193.7	BIDL	6.48	BIDL	45.9	56.7	24.3	BIDL	103.8	BIDL	BIDL	307	1.47	1.5	BIDL	
D 100-180 2R	729	BIDL	1789.7	BIDL	31.66	BIDL	1637.0	250.1	116.5	3.3	68.2	BIDL	BIDL	394	16.65	BIDL	BIDL	
D 100-180 3O	2517	BIDL	356.1	BIDL	4.94	BIDL	5330.0	1318.7	56.4	8.5	104.2	BIDL	BIDL	1907	11.41	389.7	21.6	
D 100-180 4Z	77514	BIDL	20469.8	BIDL	2.77	BIDL	10522.8	3308.7	184.0	16.5	24438.4	BIDL	66.8	268939	466.67	1187.8	21.6	0.24
D 138-141 1W	200	BIDL	137.5	BIDL	0.86	BIDL	203.8	67.6	17.1	1.1	123.7	BIDL	BIDL	995	0.96	9.2	BIDL	
D 138-141 2R	952	BIDL	3700.3	BIDL	24.95	BIDL	2451.6	521.7	338.4	4.6	88.6	2.44	14.6	697	28.19	BIDL	26.4	
D 138-141 3O	4711	BIDL	632.9	BIDL	8.26	11.5	8187.8	2765.3	124.9	12.7	84.5	4.57	13.2	2089	15.27	804.7	49.7	
D 138-141 4Z	73394	BIDL	20407.6	BIDL	5.92	BIDL	16721.3	6000.4	323.4	25.6	21572.7	5.26	61.2	256626	377.86	1786.3	48.7	0.55
D 180-195 1W	22	BIDL	57.2	BIDL	3.10	BIDL	25.9	18.5	6.1	BIDL	64.6	BIDL	BIDL	154	0.45	BIDL	BIDL	
D 180-195 2R	489	BIDL	1293.1	BIDL	49.29	BIDL	668.0	144.5	74.1	BIDL	51.1	BIDL	BIDL	215	10.34	BIDL	20.3	
D 180-195 3O	1185	BIDL	282.1	BIDL	4.33	BIDL	4923.8	529.6	26.5	8.1	111.1	BIDL	BIDL	1511	5.95	174.6	BIDL	

SEDIMENT GEOCHEMISTRY as ug metal/g sed (C as %C)

Sample*	Al**	As	Ca	Cd	Co	Cu	Fe	Mg	Mn	Mo	Na	Ni	Pb	Si	Sr	Ti	Zn	%C
D 180-195 4Z	69456	BIDL	16563.2	BIDL	2.42	BIDL	9065.7	1978.0	130.7	14.9	20533.3	BIDL	69.2	256271	388.04	1262.3	BIDL	0.11
D 195-209 1W	43	BIDL	67.8	BIDL	4.47	BIDL	34.2	21.0	6.9	BIDL	58.0	BIDL	BIDL	190	0.52	0.9	BIDL	
D 195-209 2R	357	BIDL	910.6	BIDL	38.47	BIDL	354.6	98.6	50.4	BIDL	38.8	BIDL	BIDL	145	8.20	BIDL	57.3	
D 195-209 3O	921	BIDL	225.1	BIDL	3.47	BIDL	1768.9	379.9	16.0	3.3	98.5	BIDL	BIDL	1303	5.13	98.6	BIDL	
D 195-209 4Z	65258	BIDL	14033.1	BIDL	BIDL	BIDL	3859.6	1288.5	71.8	5.5	18721.1	BIDL	59.0	236610	363.27	624.9	BIDL	0.04
E 000-012 1W	102	BIDL	21959.5	8.47	9.37	1068.8	23.8	499.7	1394.4	BIDL	406.6	1.22	BIDL	224	54.01	BIDL	2110.5	
E 000-012 2R	3083	431.1	3500.2	6.06	2.00	2249.6	16118.6	137.6	521.0	29.4	53.4	BIDL	243.6	704	17.14	BIDL	720.4	
E 000-012 3O	6260	203.7	547.4	8.09	4.59	850.9	15535.2	2796.1	440.1	30.8	79.0	4.20	1218.2	1759	23.77	708.0	2434.7	
E 000-012 4Z	57057	BIDL	5851.8	BIDL	4.36	56.7	14645.1	5241.6	611.8	23.0	6805.5	5.08	154.5	218352	119.03	1550.3	233.4	
E 000-012 5T	63000	403.7	28334.9	24.78	18.91	3761.0	43813.9	8957.3	2747.3	78.9	6773.9	11.81	1809.3	237960	198.46	2261.0	5488.3	
E 012-054 1W	40	BIDL	415.5	1.93	17.80	326.0	23.7	139.7	378.1	BIDL	92.2	BIDL	BIDL	194	1.84	BIDL	606.9	
E 012-054 2R	2285	266.2	840.0	3.72	9.98	953.5	11627.1	138.8	336.2	21.5	BIDL	BIDL	258.9	602	5.78	BIDL	436.7	
E 012-054 3O	4099	BIDL	177.9	6.40	4.05	373.8	11972.0	2009.7	202.9	23.8	68.3	3.15	623.2	1739	13.86	528.3	1894.0	
E 012-054 4Z	58170	BIDL	5802.6	BIDL	2.84	30.9	10616.3	4287.6	444.0	17.2	6637.6	BIDL	213.1	246881	136.77	1168.3	146.2	
E 012-054 5T	60355	49.7	6575.2	13.78	31.62	1510.6	32358.7	6657.4	1265.6	60.1	6267.8	BIDL	1193.4	290681	147.04	1704.2	3173.5	
E 054-084 1W	19	BIDL	276.6	1.11	27.28	252.5	9.0	61.9	220.8	BIDL	60.0	BIDL	BIDL	117	1.55	BIDL	324.2	
E 054-084 2R	974	161.2	646.6	2.03	9.60	550.3	9306.5	61.7	526.0	16.2	BIDL	BIDL	254.3	528	4.47	BIDL	270.8	
E 054-084 3O	1404	BIDL	121.6	5.95	2.65	414.6	9381.3	833.1	141.9	16.1	85.0	BIDL	197.4	1492	6.01	236.4	1646.0	
E 054-084 4Z	56090	BIDL	9663.9	BIDL	BIDL	9.4	4693.1	1705.2	327.0	8.6	12727.8	BIDL	102.8	235900	247.48	633.9	41.5	
E 054-084 5T	57056	BIDL	10170.5	10.16	39.03	1142.5	21798.7	2761.1	1116.5	38.5	12511.1	BIDL	560.6	288410	240.24	940.0	2321.3	
E 084-120 1W	41	BIDL	81.3	0.51	29.53	95.3	47.9	33.8	122.9	BIDL	43.1	BIDL	BIDL	116	1.47	BIDL	177.0	
E 084-120 2R	606	173.8	543.8	1.70	4.09	124.3	7940.4	42.6	291.1	13.4	36.6	BIDL	171.5	470	3.26	BIDL	116.3	
E 084-120 3O	960	BIDL	144.6	4.53	2.52	309.4	8039.4	520.1	84.4	13.1	108.0	BIDL	157.1	1290	5.31	153.9	1081.1	
E 084-120 4Z	63385	BIDL	11966.7	BIDL	BIDL	BIDL	4169.6	1431.8	211.7	7.9	15130.9	BIDL	72.9	268946	317.12	594.3	BIDL	
E 084-120 5T	64276	BIDL	12376.2	7.99	38.21	539.1	19007.8	2097.1	642.9	32.1	15063.3	BIDL	429.1	308727	310.79	787.2	1425.2	
E 120-156 1W	13	BIDL	60.8	BIDL	27.60	18.6	40.7	19.3	38.0	BIDL	45.1	BIDL	BIDL	126	1.46	BIDL	42.9	
E 120-156 2R	501	166.1	589.0	1.60	7.11	78.0	8969.7	31.3	169.7	14.6	37.5	BIDL	121.7	574	3.47	BIDL	117.5	
E 120-156 3O	872	BIDL	132.1	6.78	2.11	265.5	10163.5	518.3	79.5	16.6	133.4	BIDL	273.1	1249	6.58	156.6	1595.1	
E 120-156 4Z	60411	BIDL	11814.3	BIDL	BIDL	BIDL	7162.3	1622.2	271.4	11.7	14709.7	BIDL	83.5	260211	286.63	910.7	21.9	
E 120-156 5T	61800	BIDL	12224.9	11.33	40.46	388.2	26614.7	2327.3	530.7	43.4	14862.1	BIDL	544.4	305190	287.61	1156.3	1944.4	

SEDIMENT GEOCHEMISTRY as ug metal/g sed (C as %C)

Sample*	Al**	As	Ca	Cd	Co	Cu	Fe	Mg	Mn	Mo	Na	Ni	Pb	Si	Sr	Ti	Zn	%C
E 156-158 1W	12	BIDL	99.9	BIDL	52.81	20.1	17.6	28.8	190.8	BIDL	65.0	BIDL	BIDL	137	2.06	BIDL	38.3	
E 156-158 2R	751	16.2	531.2	BIDL	23.02	196.1	19907.2	34.1	684.1	30.3	35.9	BIDL	133.4	575	4.64	BIDL	95.2	
E 156-158 3O	1105	BIDL	186.3	4.08	2.76	439.9	12287.2	523.1	55.7	20.3	112.0	BIDL	131.5	1350	6.25	154.9	735.4	
E 156-158 4Z	63420	BIDL	11303.3	BIDL	BIDL	BIDL	3834.1	1331.5	114.8	6.9	15295.2	BIDL	80.2	279350	309.13	432.2	BIDL	
E 156-158 5T	66788	BIDL	11761.0	6.12	78.27	673.9	34186.0	2020.5	926.4	55.1	15868.8	BIDL	385.8	304394	321.29	634.2	950.2	
F 000-006 1W	38	BIDL	165.5	BIDL	1.66	10.1	76.2	33.3	10.4	BIDL	52.6	BIDL	4.9	221	0.98	1.5	11.1	
F 000-006 2R	1105	122.2	1828.4	3.59	63.86	808.2	6894.8	206.9	1008.6	11.5	58.3	BIDL	288.5	911	16.51	BIDL	903.3	
F 000-006 3O	1759	BIDL	238.1	1.65	5.71	198.2	12514.0	1013.0	131.6	21.7	89.8	BIDL	112.7	1573	6.66	290.5	507.1	
F 000-006 4Z	65447	BIDL	13481.4	BIDL	BIDL	BIDL	7363.4	1921.6	279.3	12.4	16549.0	BIDL	91.3	253543	328.63	709.0	56.1	
F 000-006 5T	69200	BIDL	14827.9	5.64	64.93	881.8	25366.0	3375.6	1257.1	42.4	16813.5	BIDL	521.3	279759	342.31	1054.6	1492.0	0.32
F 006-030 1W	24	BIDL	175.1	BIDL	1.64	4.4	41.7	21.9	5.4	BIDL	40.1	BIDL	BIDL	111	0.87	0.8	3.9	
F 006-030 2R	714	30.1	1136.7	1.67	43.92	294.6	3711.5	85.8	485.0	6.2	42.5	BIDL	86.6	560	7.90	BIDL	315.7	
F 006-030 3O	937	BIDL	162.9	BIDL	3.15	112.5	7945.9	425.8	46.3	15.7	92.2	BIDL	32.7	1285	4.02	100.9	233.8	
F 006-030 4Z	69862	BIDL	13505.4	BIDL	BIDL	BIDL	7725.3	1326.7	106.4	13.3	17193.4	BIDL	81.3	257615	351.10	644.9	BIDL	0.09
F 030-054 1W	23	BIDL	89.0	BIDL	2.12	7.5	64.8	16.6	9.8	BIDL	36.2	BIDL	BIDL	111	0.70	BIDL	4.1	
F 030-054 2R	964	33.2	1317.1	2.68	33.64	476.7	5333.1	97.0	1032.0	9.3	34.9	BIDL	108.6	821	9.75	BIDL	263.6	
F 030-054 3O	967	BIDL	194.8	3.52	4.06	409.6	20167.4	429.4	79.4	32.0	76.8	BIDL	47.3	1347	3.83	115.9	757.0	
F 030-054 4Z	62897	BIDL	11423.5	BIDL	4.16	BIDL	20525.7	1625.6	206.7	31.0	14286.2	BIDL	81.4	249354	298.64	1261.2	27.5	
F 030-054 5T	66936	BIDL	12660.3	6.44	38.82	868.9	42277.5	2246.4	1020.3	66.8	14912.2	BIDL	275.2	270736	311.15	1442.1	1132.9	0.08
F 054-073 1W	64	BIDL	62.0	BIDL	1.69	34.8	61.6	17.3	BIDL	BIDL	51.1	BIDL	BIDL	227	0.60	1.9	BIDL	
F 054-073 2R	874	BIDL	1216.7	BIDL	26.72	482.0	877.8	111.5	17.6	BIDL	48.8	BIDL	18.2	360	10.65	BIDL	60.5	
F 054-073 3O	1140	BIDL	208.7	BIDL	2.33	262.7	3511.5	489.7	18.0	5.6	81.1	BIDL	BIDL	1418	5.67	125.9	63.3	
F 054-073 4Z	71104	BIDL	18091.7	BIDL	2.21	BIDL	10108.9	1861.3	107.1	16.4	21342.0	BIDL	80.4	249773	446.87	1170.4	BIDL	
F 054-073 5T	70701	BIDL	17237.1	BIDL	27.29	682.7	13089.7	2375.7	132.5	21.0	20912.8	BIDL	97.3	253004	435.69	1299.1	133.3	0.06
F 073-077 1W	43	BIDL	123.2	0.52	2.31	8.0	34.8	29.3	4.1	3.1	81.6	BIDL	BIDL	203	0.90	1.0	18.8	
F 073-077 2R	1298	6.3	2893.1	35.08	63.86	316.0	1477.8	304.1	82.0	2.9	77.6	8.57	12.2	570	22.57	BIDL	806.5	
F 073-077 3O	2665	BIDL	410.4	3.69	8.54	248.0	9244.8	1240.5	48.2	18.8	102.3	6.19	BIDL	1956	9.29	381.3	160.9	
F 073-077 4Z	66349	BIDL	18807.3	BIDL	5.41	BIDL	19288.7	4031.9	217.0	29.4	18737.8	5.55	76.2	259856	380.49	1929.1	42.1	
F 073-077 5T	69023	BIDL	19296.3	33.75	67.02	493.2	29266.7	5261.4	314.1	53.5	18738.2	18.43	90.0	273163	392.03	2379.5	906.7	1.30

SEDIMENT GEOCHEMISTRY as ug metal/g sed (C as %C)

Sample*	Al**	As	Ca	Cd	Co	Cu	Fe	Mg	Mn	Mo	Na	Ni	Pb	Si	Sr	Ti	Zn	%C
G 000-011 1W	17	5.0	79.7	BIDL	5.87	6.6	194.6	32.6	20.6	BIDL	123.1	BIDL	BIDL	175	0.59	BIDL	15.1	
G 000-011 2R	597	53.9	783.2	BIDL	19.81	204.1	7421.8	109.3	82.1	12.1	79.4	BIDL	109.2	305	8.92	2.3	78.4	
G 000-011 3O	1947	BIDL	212.6	3.76	5.18	309.3	21009.7	1085.0	151.6	34.8	324.1	BIDL	522.4	1649	19.88	397.4	1003.7	
G 000-011 4Z	61216	BIDL	15729.1	BIDL	4.34	9.7	14645.2	4581.4	658.4	22.2	14642.7	BIDL	135.9	235425	281.72	1409.4	149.3	
G 000-011 5T	62723	BIDL	14667.5	4.66	29.93	510.1	39841.1	5406.0	834.9	64.4	15104.3	BIDL	768.0	248915	300.97	1850.8	1322.5	1.67
G 011-033 1W	14	12.9	58.1	BIDL	3.05	4.1	167.6	14.5	14.2	BIDL	49.6	BIDL	4.9	146	0.90	BIDL	73.6	
G 011-033 2R	947	149.9	563.5	2.77	23.66	265.5	11964.9	146.7	159.2	20.9	BIDL	BIDL	538.3	490	11.86	2.2	939.9	
G 011-033 3O	3130	BIDL	957.6	4.44	9.03	616.7	25941.3	1792.1	238.4	42.5	53.3	5.02	272.2	1826	9.88	535.4	1235.4	
G 011-033 4Z	62006	BIDL	13515.1	BIDL	4.35	10.5	13529.2	4695.7	717.7	21.7	13266.4	BIDL	139.4	234152	256.36	1353.9	172.9	
G 011-033 5T	64786	BIDL	13356.6	7.54	33.58	840.0	44629.4	6224.9	1029.9	73.2	13390.2	BIDL	899.6	243686	268.47	1929.3	2320.8	1.57
G 033-048 1W	12	BIDL	92.9	BIDL	3.40	13.3	13.5	17.1	4.4	BIDL	25.2	BIDL	BIDL	69	0.73	BIDL	5.7	
G 033-048 2R	1998	31.5	1069.8	4.52	32.13	1030.9	4642.3	72.2	209.8	8.0	BIDL	BIDL	89.8	927	6.48	BIDL	293.7	
G 033-048 3O	1334	BIDL	404.3	2.88	7.29	1195.0	33728.6	539.2	63.0	51.3	48.3	3.64	57.3	1369	5.69	124.0	677.2	
G 033-048 4Z	61650	BIDL	10834.3	BIDL	3.02	10.9	13626.5	1853.6	178.9	22.3	13524.8	BIDL	94.3	222137	283.64	684.4	49.2	
G 033-048 5T	60833	BIDL	9918.9	6.03	35.55	2044.3	44848.2	2298.4	332.5	70.4	12949.8	BIDL	210.9	227153	269.99	813.7	1013.4	0.18
G 048-063 1W	6	BIDL	121.2	BIDL	1.53	BIDL	7.8	20.6	4.4	BIDL	27.5	BIDL	BIDL	73	1.00	BIDL	BIDL	
G 048-063 2R	2458	37.2	1402.7	1.14	28.22	515.1	7603.0	82.9	515.1	13.5	BIDL	BIDL	97.0	1265	10.19	BIDL	177.4	
G 048-063 3O	1696	BIDL	274.0	4.63	6.43	688.8	34906.4	634.1	166.5	53.8	44.4	3.20	70.7	1431	4.60	118.1	1037.8	
G 048-063 4Z	60515	BIDL	9558.2	BIDL	2.37	16.8	12817.5	2291.5	173.4	20.2	11772.6	BIDL	94.0	206402	263.42	669.5	60.5	
G 048-063 5T	62502	BIDL	9671.9	5.42	29.88	1196.5	47607.9	2825.2	501.9	75.3	11679.1	BIDL	236.5	219228	258.18	804.1	1272.3	0.14
G 063-077 1W	24	BIDL	116.2	BIDL	4.73	5.5	25.5	24.9	3.0	BIDL	45.2	BIDL	BIDL	132	0.66	BIDL	BIDL	
G 063-077 2R	2662	BIDL	2365.3	BIDL	52.37	405.3	2522.5	126.6	64.2	4.6	59.1	BIDL	24.0	2054	17.41	BIDL	37.6	
G 063-077 3O	3529	BIDL	2184.6	BIDL	4.41	250.7	9777.8	494.8	32.3	16.0	79.2	BIDL	13.1	2002	17.39	127.8	70.1	
G 063-077 4Z	60954	BIDL	28566.0	BIDL	2.48	BIDL	12051.3	9548.5	186.9	18.2	16786.6	BIDL	62.1	249664	319.34	1024.6	23.9	
G 063-077 5T	62326	BIDL	28774.2	BIDL	46.05	547.9	22333.6	9192.7	231.3	36.7	15137.1	BIDL	88.8	251813	320.52	1146.4	113.8	0.18
G 077-096 1W	44	BIDL	47.0	BIDL	2.15	6.7	37.6	16.0	2.1	BIDL	59.2	BIDL	BIDL	127	0.45	BIDL	BIDL	
G 077-096 2R	658	BIDL	1406.3	7.37	34.89	167.7	999.4	152.5	37.2	1.7	55.7	BIDL	9.6	267	10.89	BIDL	46.7	
G 077-096 3O	1304	BIDL	235.4	1.32	4.09	75.8	8168.0	615.7	29.1	12.9	79.8	BIDL	BIDL	1572	4.68	177.1	33.8	
G 077-096 4Z	68387	BIDL	16592.2	BIDL	4.33	BIDL	17887.3	2231.8	138.7	27.4	19406.0	BIDL	84.9	250072	375.35	1521.9	BIDL	
G 077-096 5T	65709	BIDL	14898.9	7.36	35.72	201.4	25465.1	2646.0	177.0	39.4	18622.1	BIDL	81.9	250908	354.59	1651.1	78.0	0.11

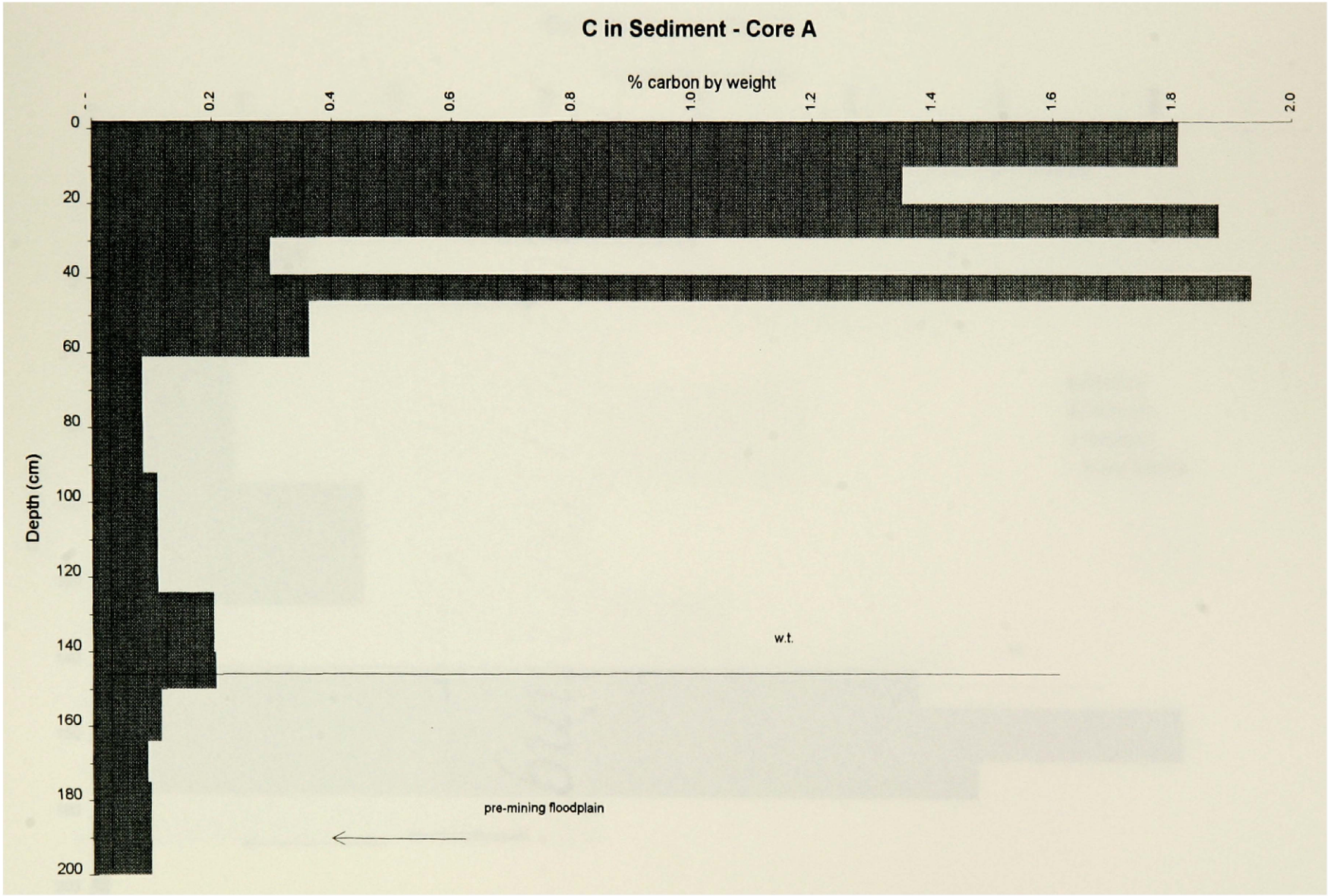
SEDIMENT GEOCHEMISTRY as ug metal/g sed (C as %C)

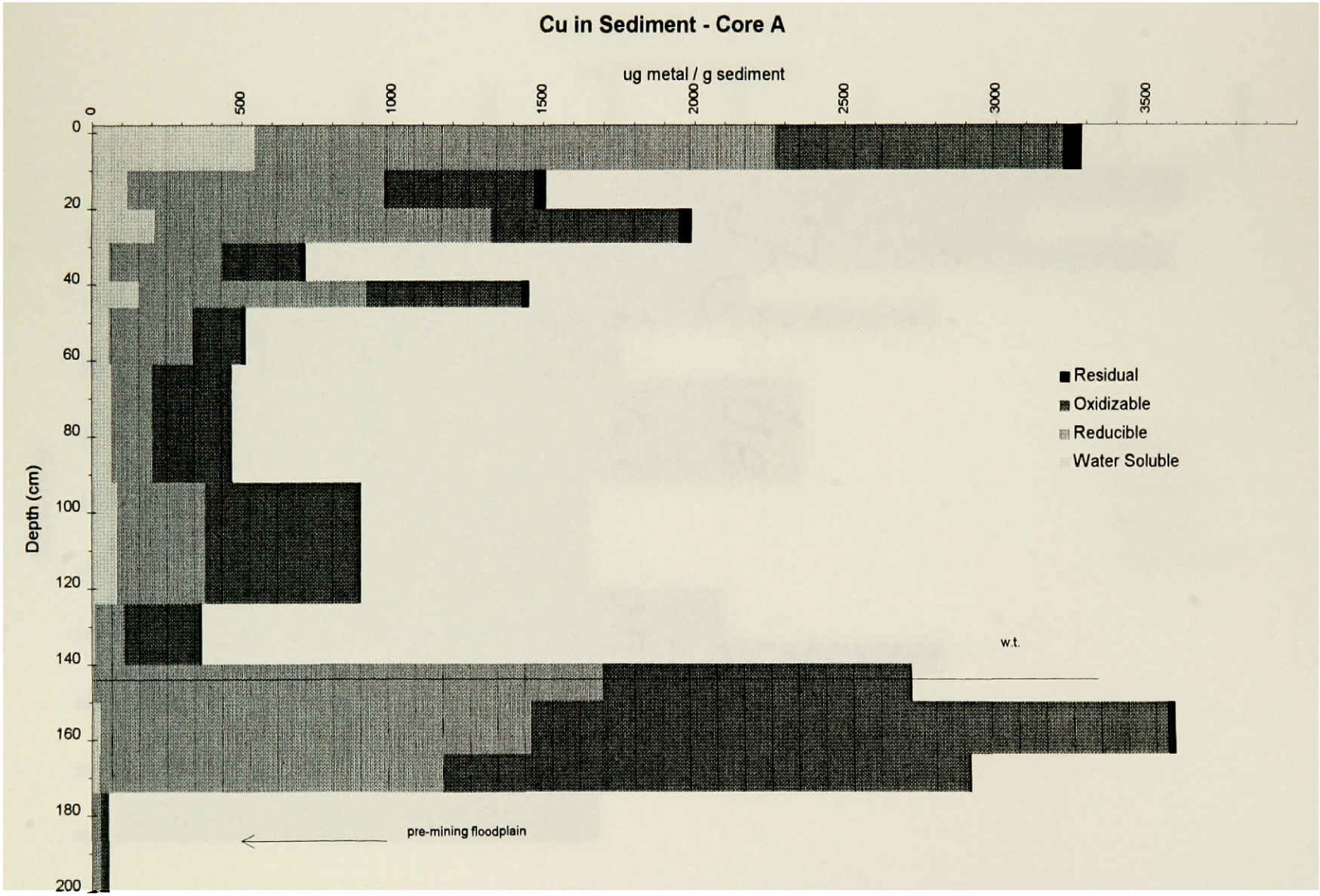
Sample*	Al**	As	Ca	Cd	Co	Cu	Fe	Mg	Mn	Mo	Na	Ni	Pb	Si	Sr	Ti	Zn	%C
Blue crust 7-1 1W	93	BIDL	28118.6	31.51	26.51	2004.4	91.0	2079.7	6123.9	BIDL	1992.4	4.88	BIDL	218	49.76	18.9	9255.3	
Blue crust 7-1 2R	2023	460.5	13348.8	9.65	3.17	2187.9	9757.7	255.7	968.4	19.0	165.3	BIDL	256.1	606	42.40	2.3	1243.9	
Blue crust 7-1 3O	5746	BIDL	2101.4	5.85	4.90	718.8	13324.8	2635.7	419.5	26.2	123.3	3.95	1166.8	1992	35.75	693.7	1655.6	
Blue crust 7-1 4Z	44273	BIDL	6368.1	BIDL	3.23	43.6	12045.9	3924.2	597.5	18.8	6998.7	BIDL	128.5	195889	117.87	1167.2	208.5	1.49
Yllw crst 9-19 1W	14069	111.6	17914.4	25.68	51.09	3999.2	61722.4	10941.6	7583.1	92.1	9836.0	33.35	68.0	14	33.54	424.6	7674.6	
Yllw crst 9-19 2R	339	9.0	332.6	BIDL	1.07	120.5	3728.4	209.4	160.8	6.5	281.7	BIDL	155.8	42	3.99	47.7	134.1	
Yllw crst 9-19 3O	87	BIDL	BIDL	1.23	BIDL	46.9	2678.2	12.9	5.7	4.2	60.4	BIDL	60.0	430	2.92	51.8	314.9	
Yllw crst 9-19 4Z	15421	BIDL	4111.0	BIDL	BIDL	BIDL	3441.1	1195.4	174.5	5.3	4061.7	BIDL	31.6	77369	70.65	385.9	36.8	0.55
Blue crust 9-19 1W	150	BIDL	21871.1	84.65	17.02	2782.1	8.2	8685.0	9075.6	0.7	6032.2	7.37	BIDL	170	57.69	2.3	16007.2	
Blue crust 9-19 2R	1657	308.4	4151.4	9.67	1.57	2239.2	7473.4	523.9	911.2	14.5	347.4	BIDL	242.0	535	28.37	2.0	1270.7	
Blue crust 9-19 3O	3690	BIDL	380.7	5.94	3.45	456.6	9606.5	1838.7	390.3	19.7	88.5	3.13	619.2	1861	21.81	483.3	1838.6	
Blue crust 9-19 4Z	35217	BIDL	5935.7	BIDL	2.31	29.5	8595.8	3198.9	569.8	13.9	5987.8	BIDL	127.4	180318	103.05	894.9	166.8	0.92
detection limit	*0.06*	*0.06*	*0.15*	*0.009*	*0.009*	*0.04*	*0.04*	*0.09*	*0.02*	*0.016*	*0.35*	*0.02*	*0.095*	*0.09*	*0.008*	*0.02*	*0.095*	*0*

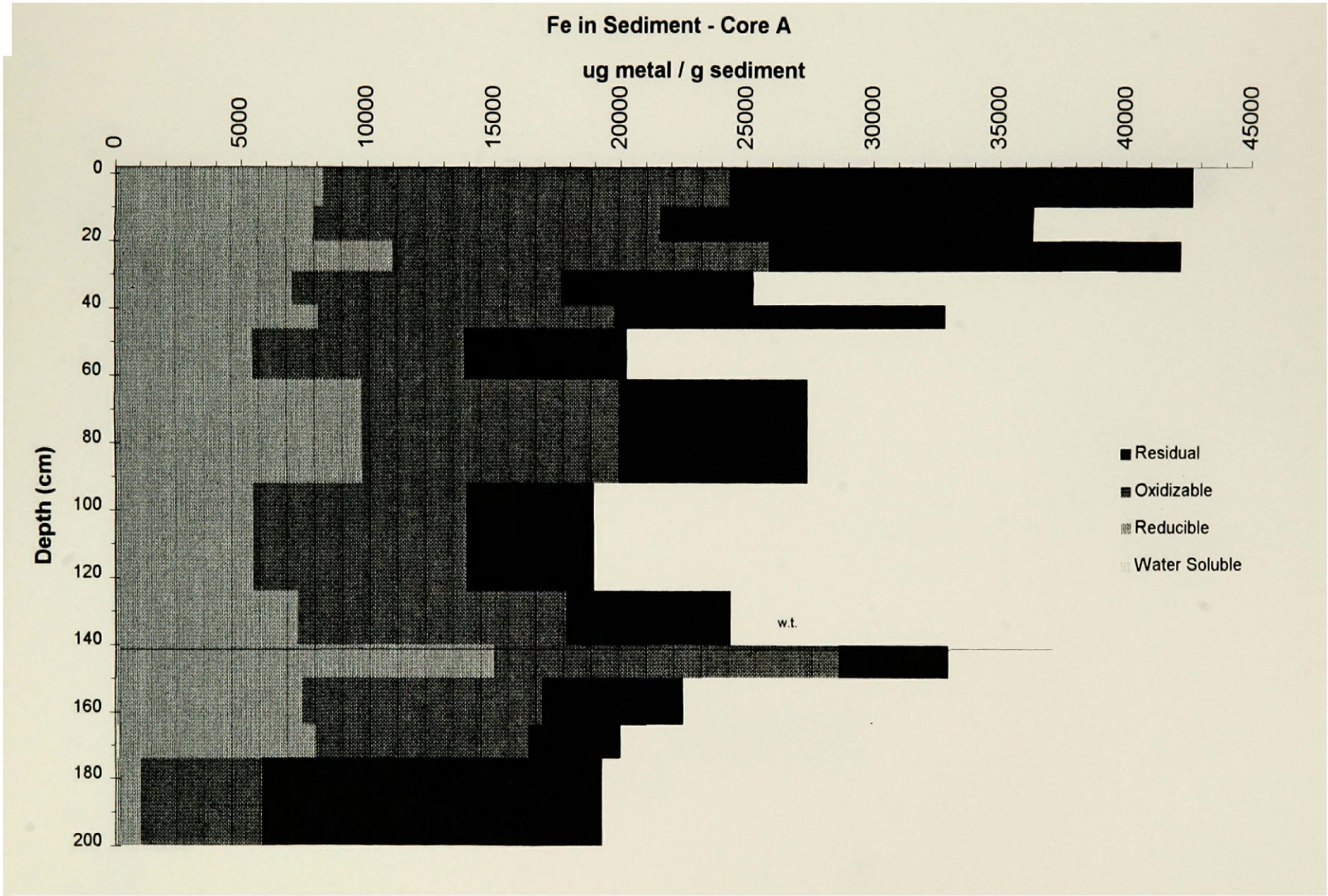
*Sample Name: first letter indicates core location, range indicates depth of sample in cm, number/letter combination indicates extraction procedure used (i.e. 1W=water, 2R=reducible, 3O=oxidizable, 4Z=residual, 5T=total digest).

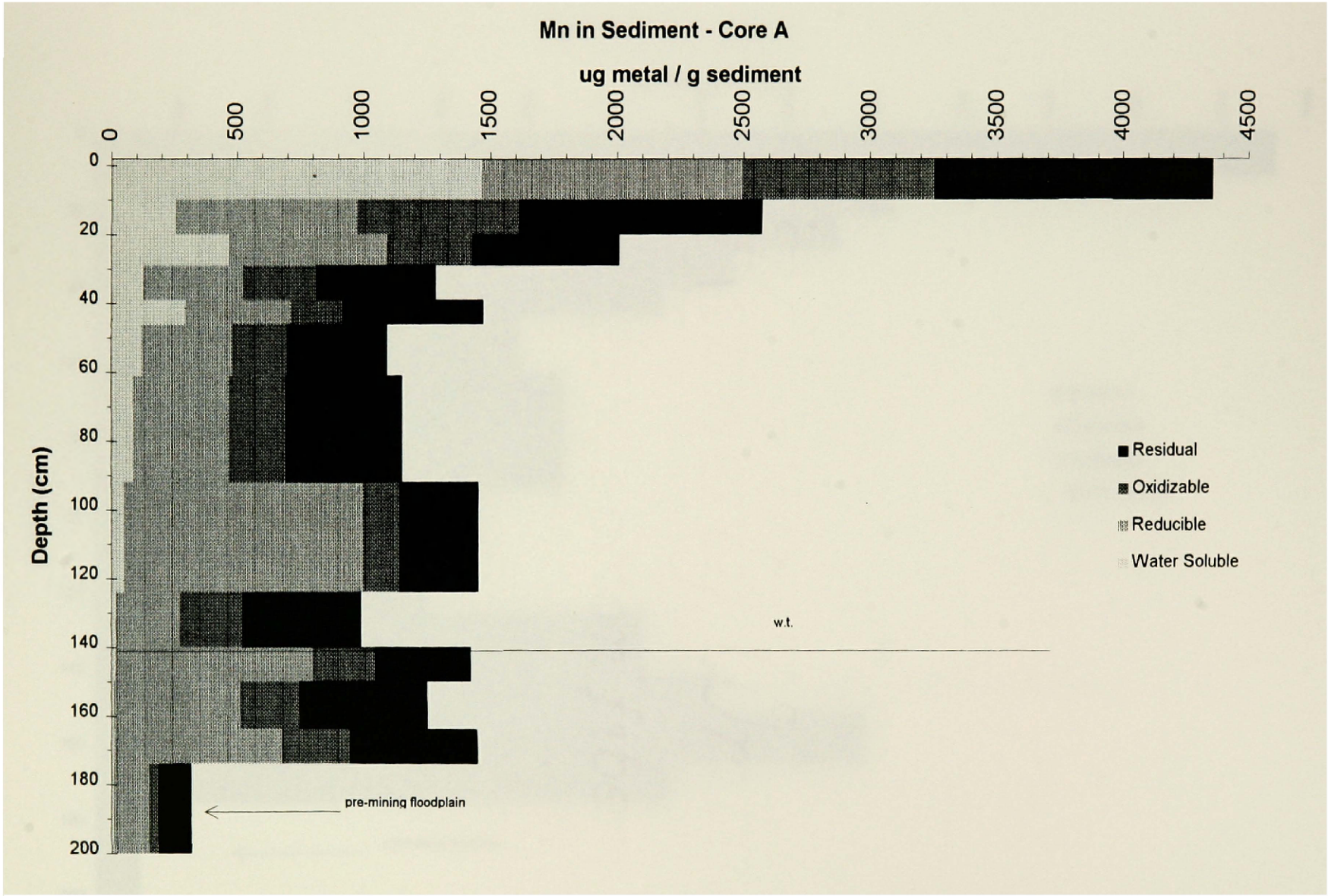
** All concentrations given in ppm except carbon which is given in percent total carbon in sample.

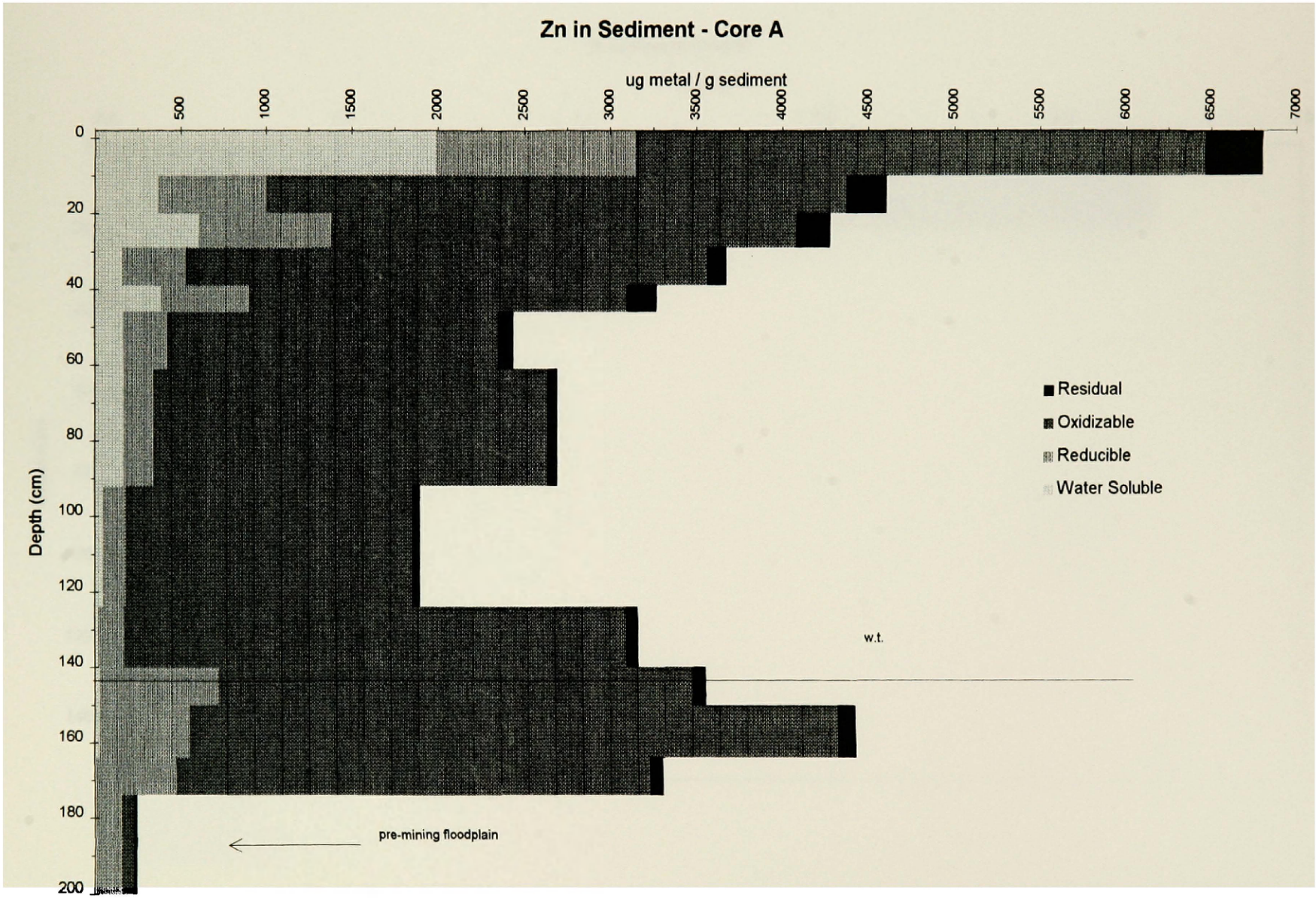
BIDL = Below instument detection limit (3 times the standard deviation of 10 analyses plus the average).

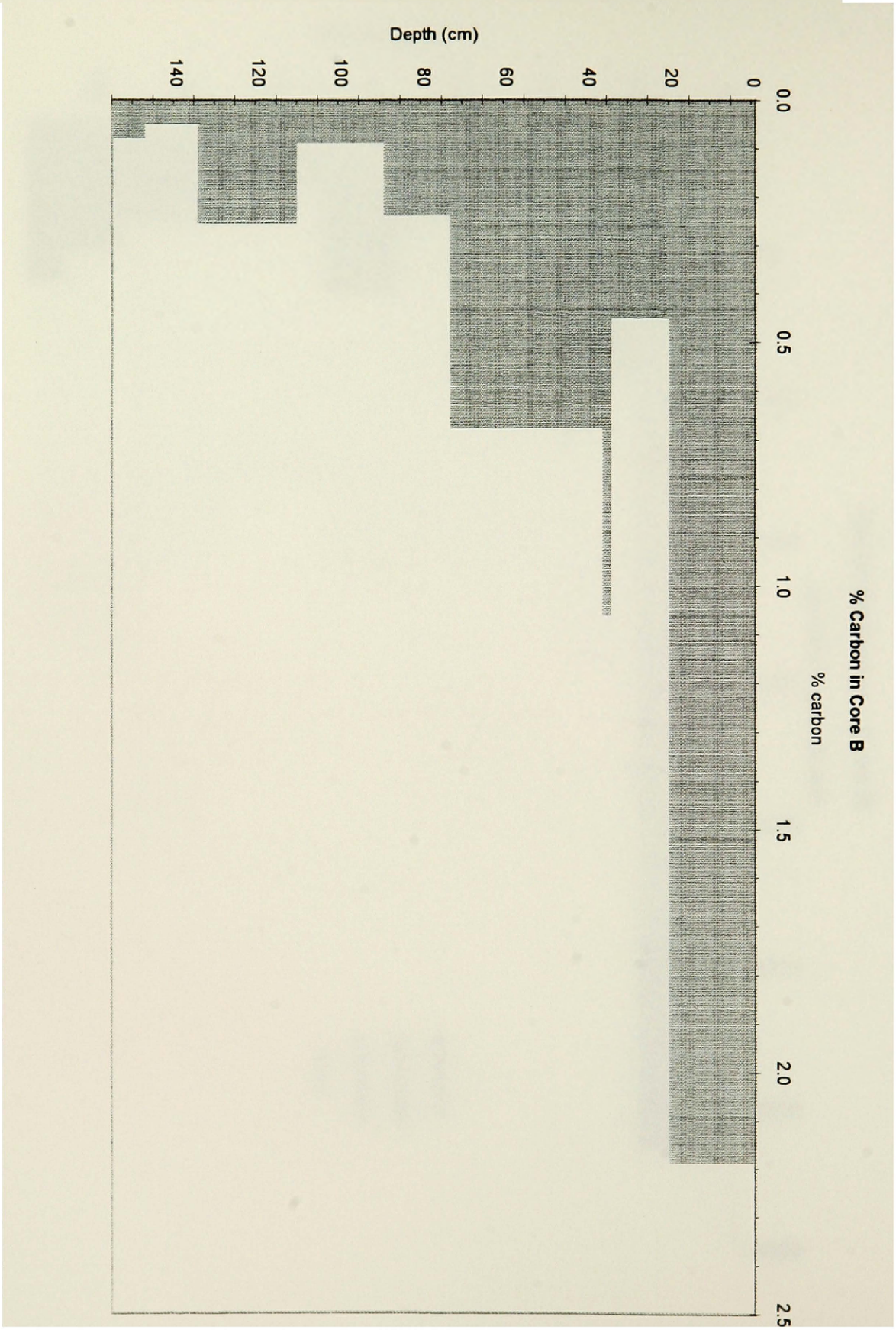

C in Sediment - Core A
% carbon by weight
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
0
20
40
60
80
100
120
140
160
180
200
Depth (cm)
w.t.
pre-mining floodplain

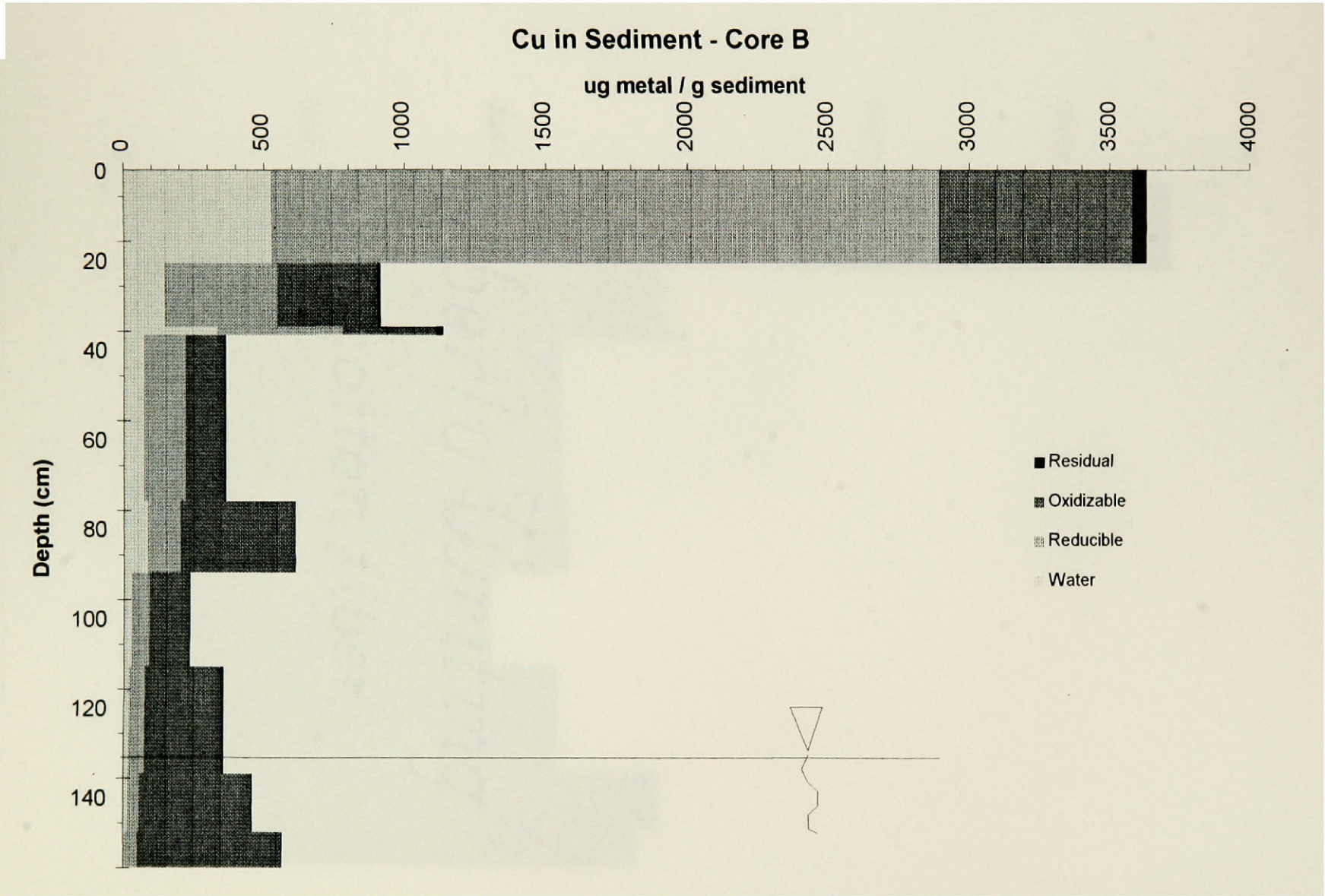

Cu in Sediment - Core A
ug metal / g sediment
0
500
1000
1500
2000
2500
3000
3500
Depth (cm)
0
20
40
60
80
100
120
140
160
180
200
Residual
Oxidizable
Reducible
Water Soluble
w.t.
pre-mining floodplain

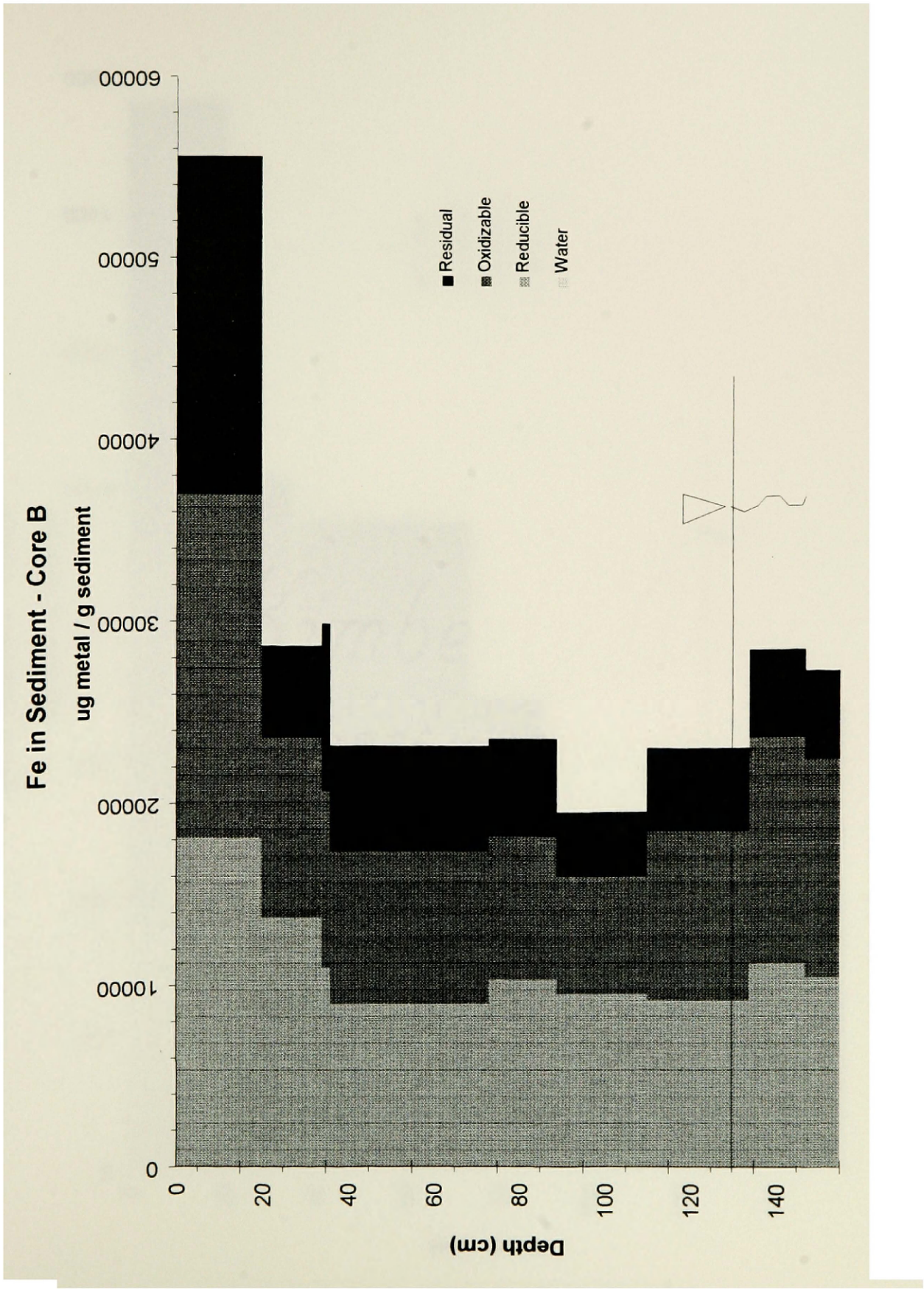

Fe in Sediment - Core A
ug metal / g sediment
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
Depth (cm)
0
20
40
60
80
100
120
140
160
180
200
w.t.
Residual
Oxidizable
Reducible
Water Soluble

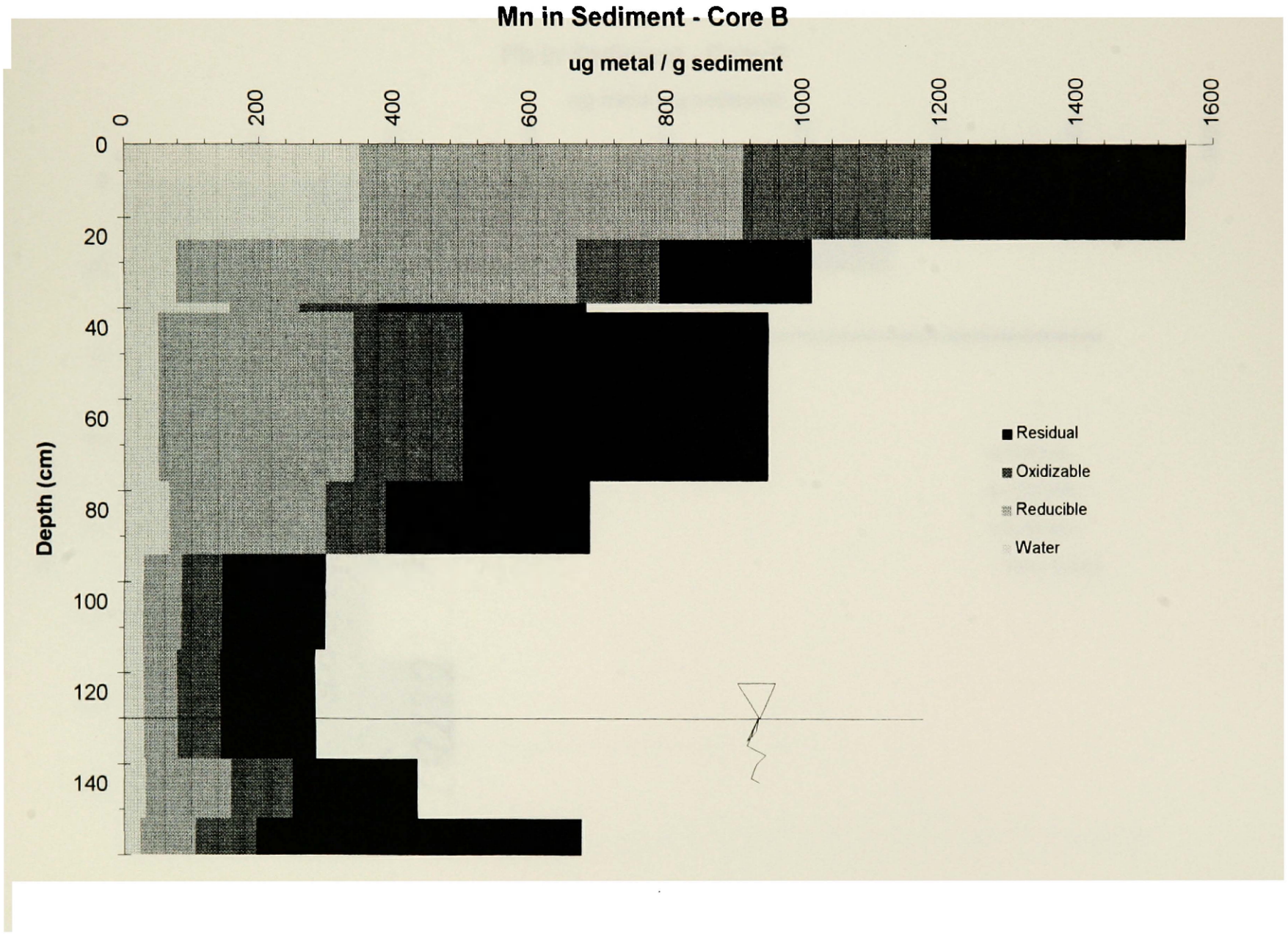

Mn in Sediment - Core A
ug metal / g sediment
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Depth (cm)
0
20
40
60
80
100
120
140
160
180
200
w.t.
pre-mining floodplain
Residual
Oxidizable
Reducible
Water Soluble

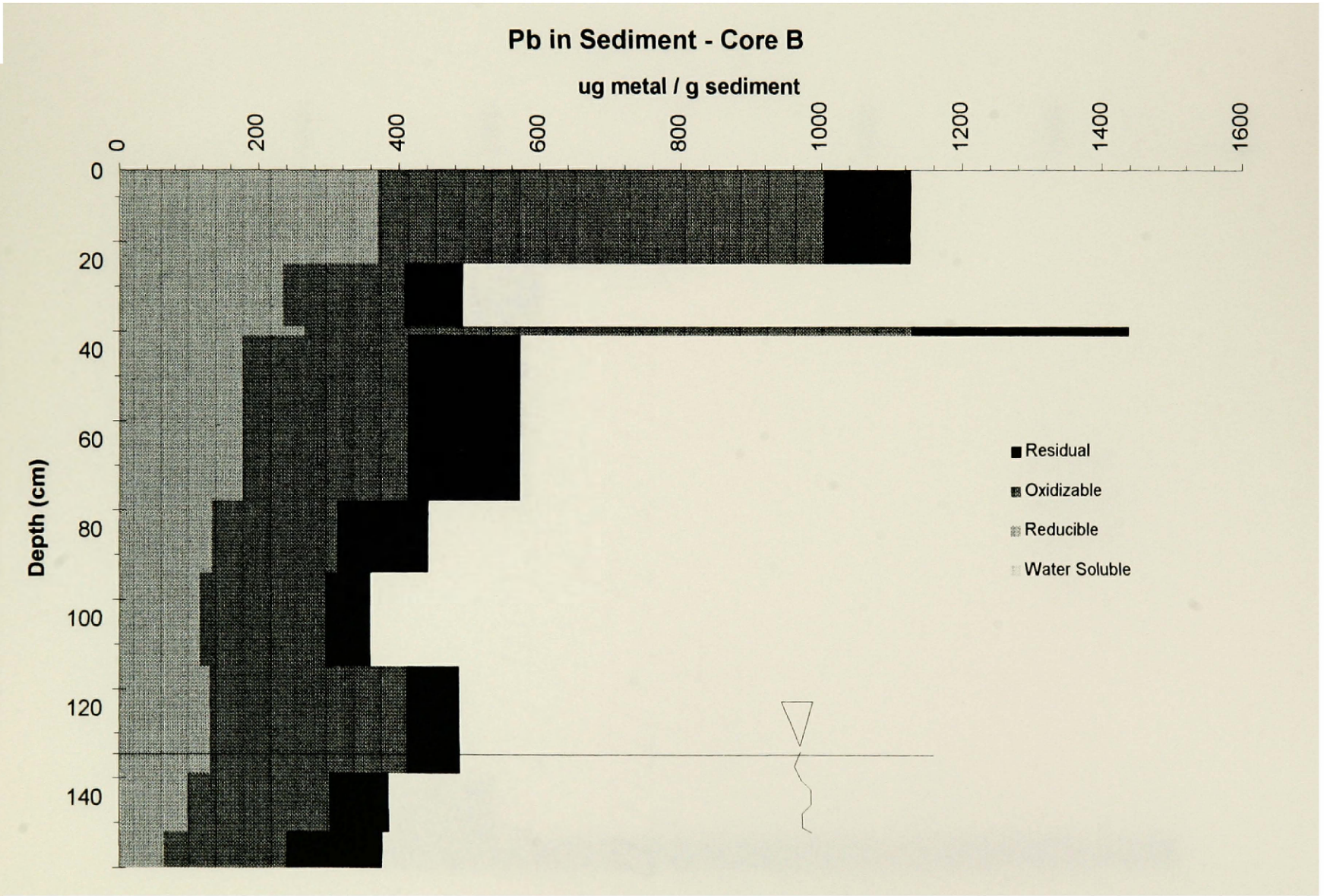

Zn in Sediment - Core A
ug metal / g sediment
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
Depth (cm)
0
20
40
60
80
100
120
140
160
180
200
Residual
Oxidizable
Reducible
Water Soluble
w.t.
pre-mining floodplain

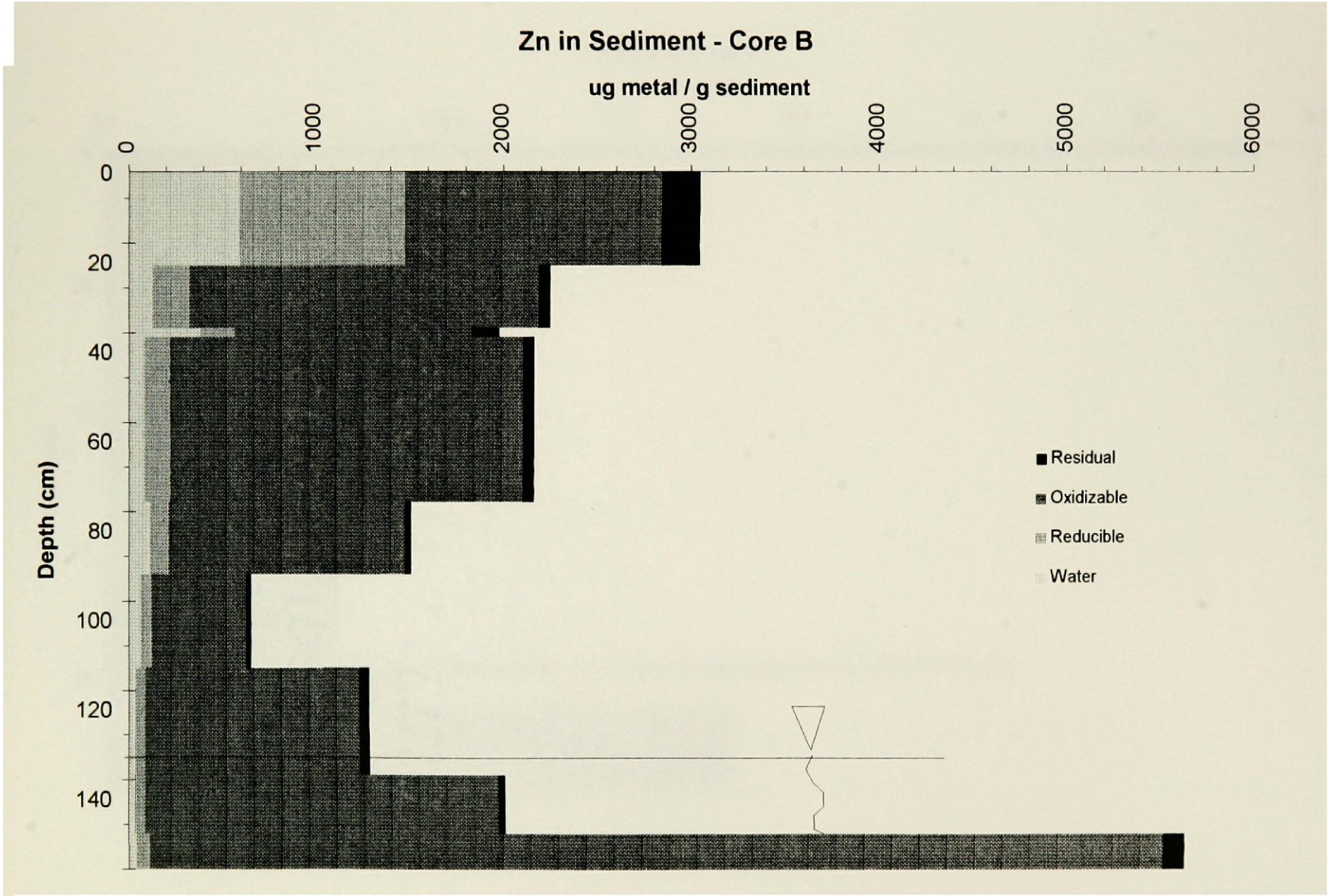

% Carbon in Core B
% carbon
Depth (cm)
0.0
0.5
1.0
1.5
2.0
2.5
0
20
40
60
80
100
120
140

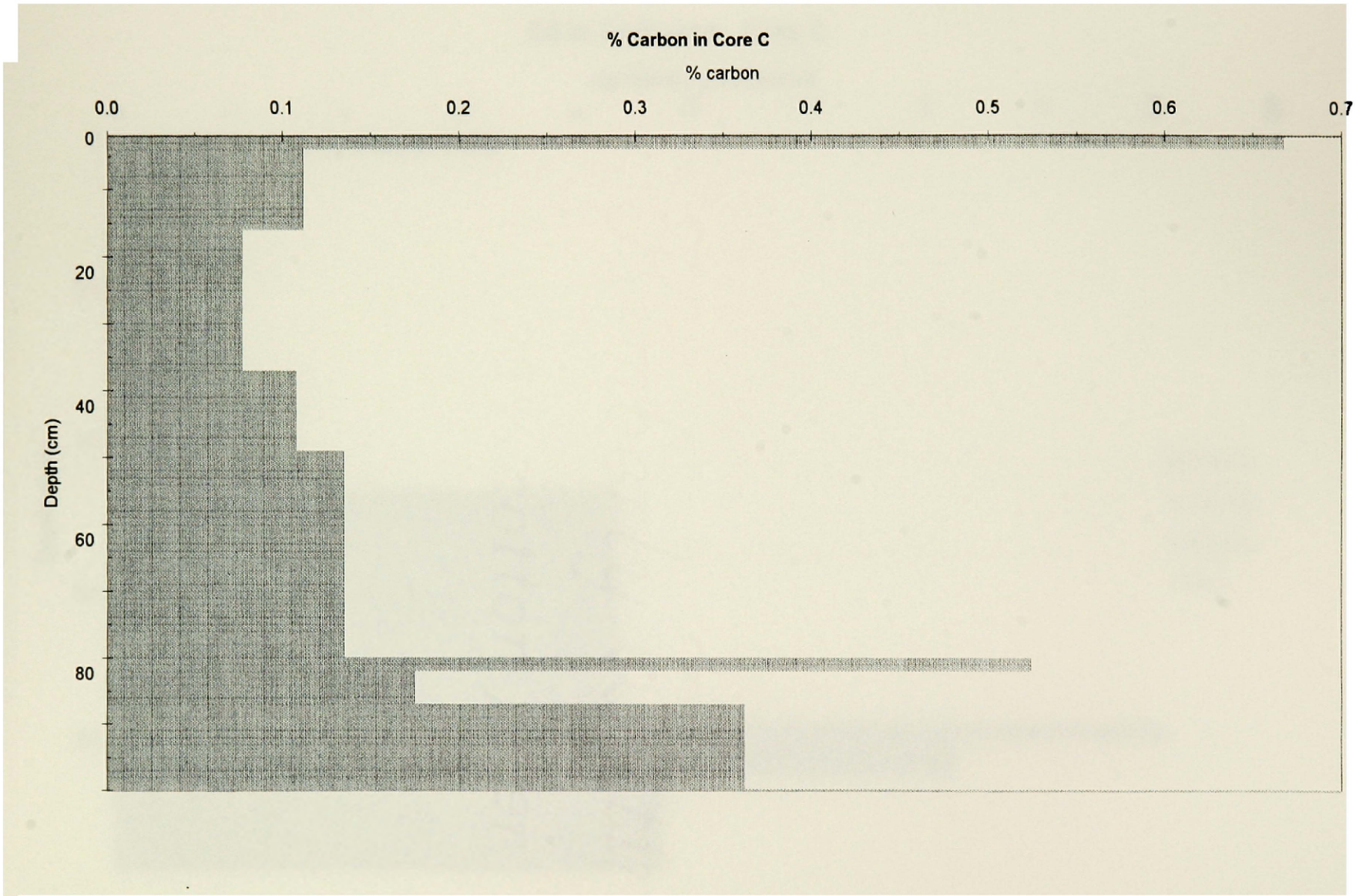

Cu in Sediment - Core B
ug metal / g sediment
0
500
1000
1500
2000
2500
3000
3500
4000
Depth (cm)
0
20
40
60
80
100
120
140
Residual
Oxidizable
Reducible
Water

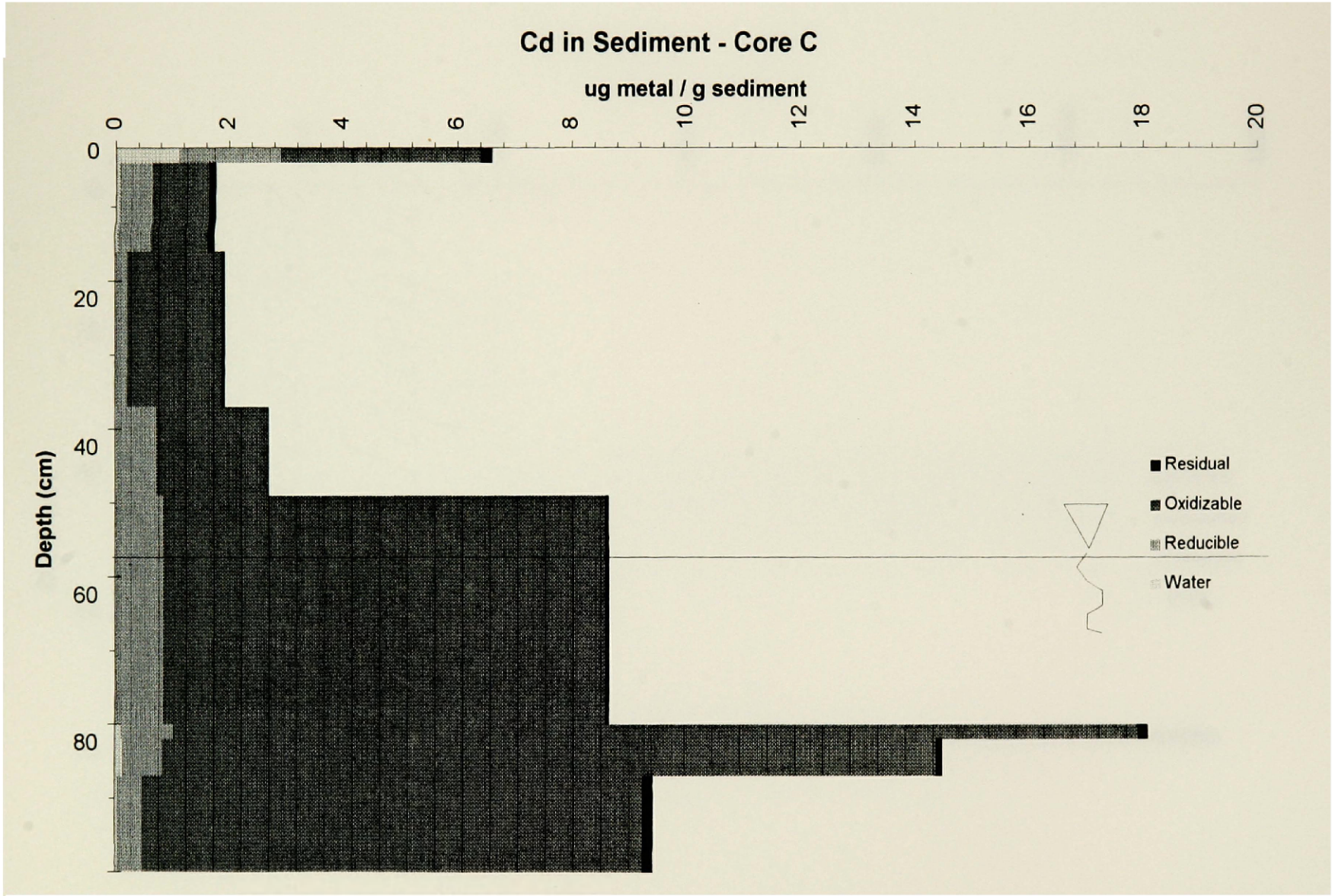

Fe in Sediment - Core B
ug metal / g sediment
Depth (cm)
Residual
Oxidizable
Reducible
Water
0
10000
20000
30000
40000
50000
60000
0
20
40
60
80
100
120
140

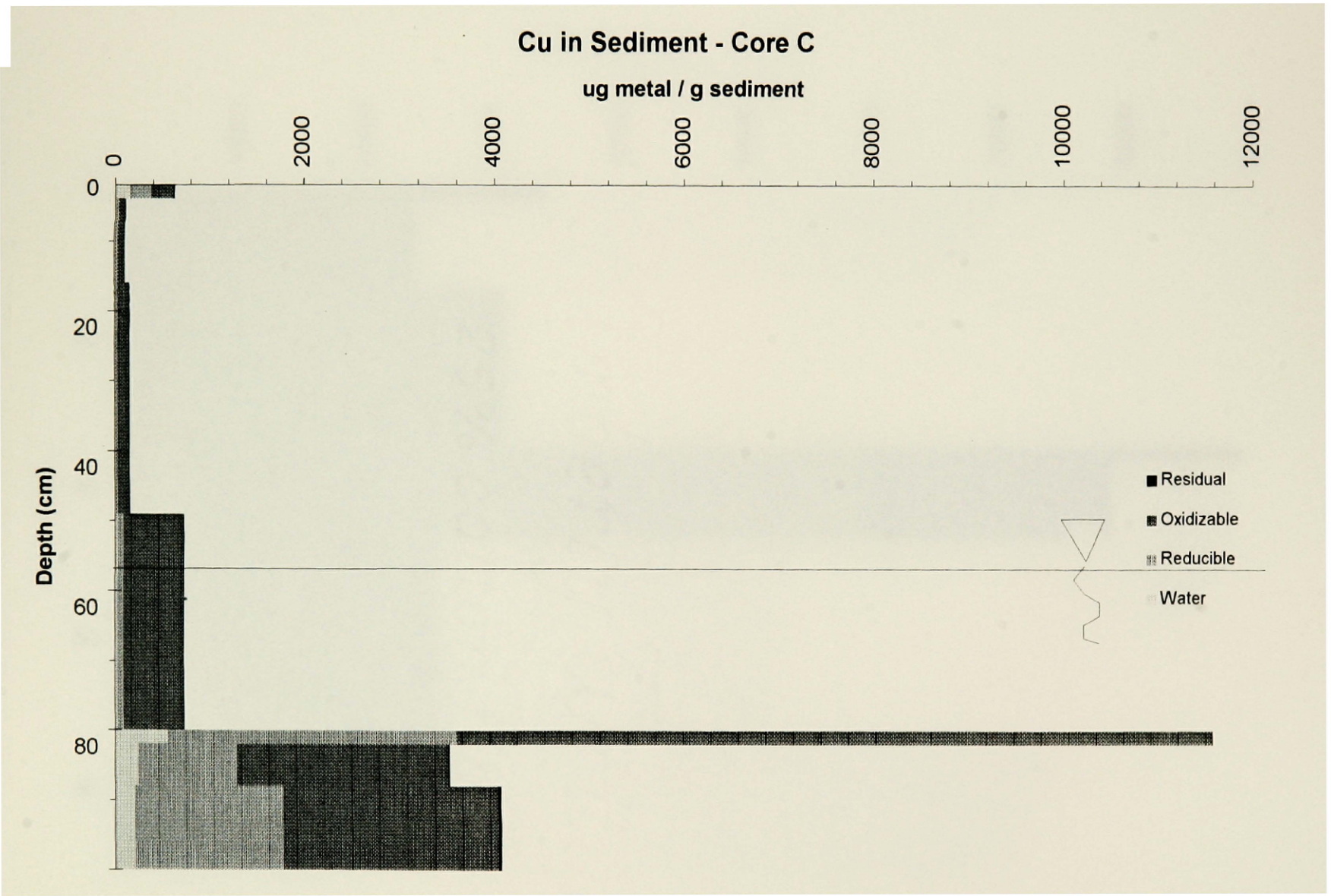

Mn in Sediment - Core B
ug metal / g sediment
0
200
400
600
800
1000
1200
1400
1600
Depth (cm)
0
20
40
60
80
100
120
140
Residual
Oxidizable
Reducible
Water

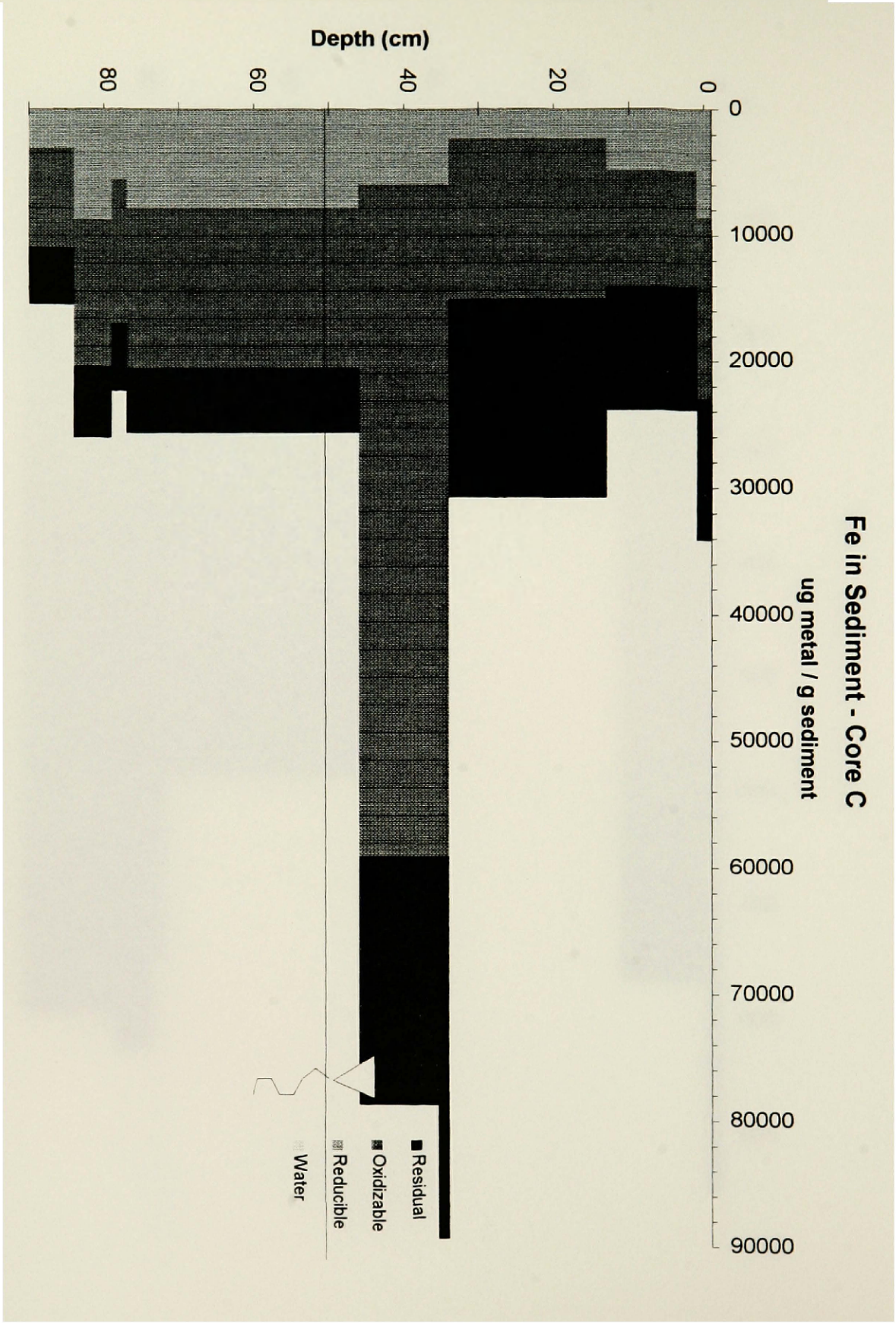

Pb in Sediment - Core B
ug metal / g sediment
0
200
400
600
800
1000
1200
1400
1600
Depth (cm)
0
20
40
60
80
100
120
140
Residual
Oxidizable
Reducible
Water Soluble

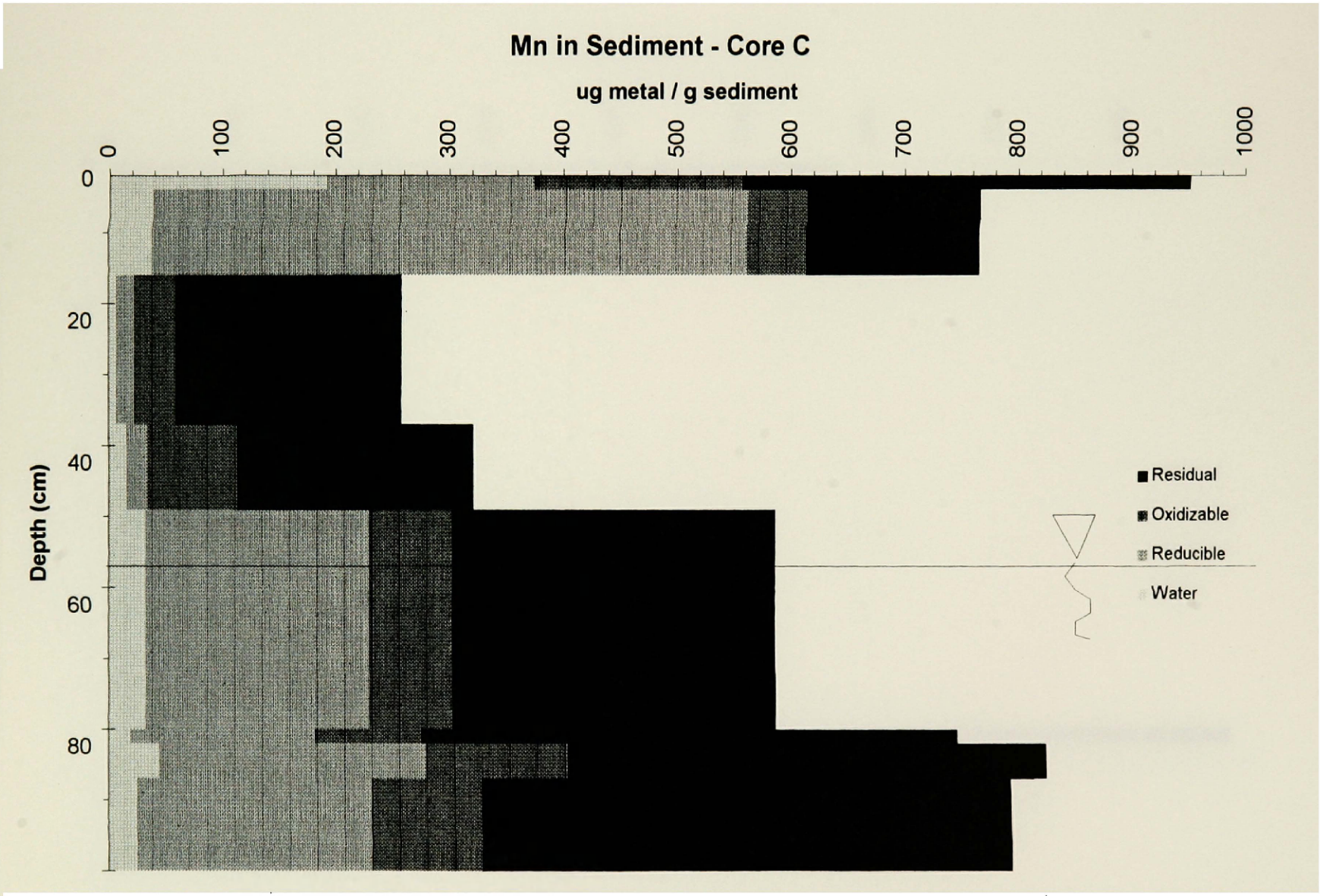

Zn in Sediment - Core B
ug metal / g sediment
0
1000
2000
3000
4000
5000
6000
Depth (cm)
0
20
40
60
80
100
120
140
Residual
Oxidizable
Reducible
Water

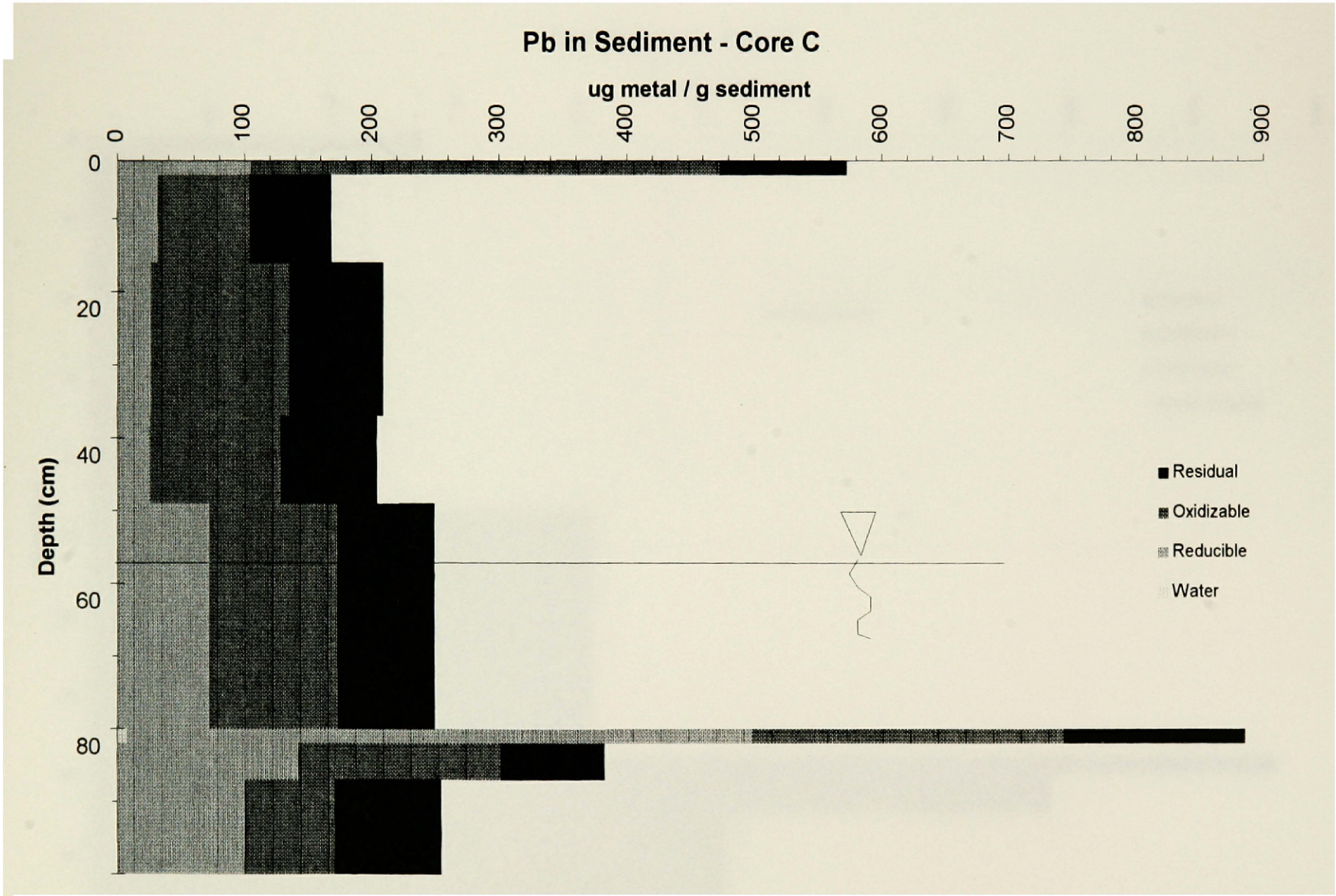

% Carbon in Core C
% carbon
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0
20
40
60
80
Depth (cm)

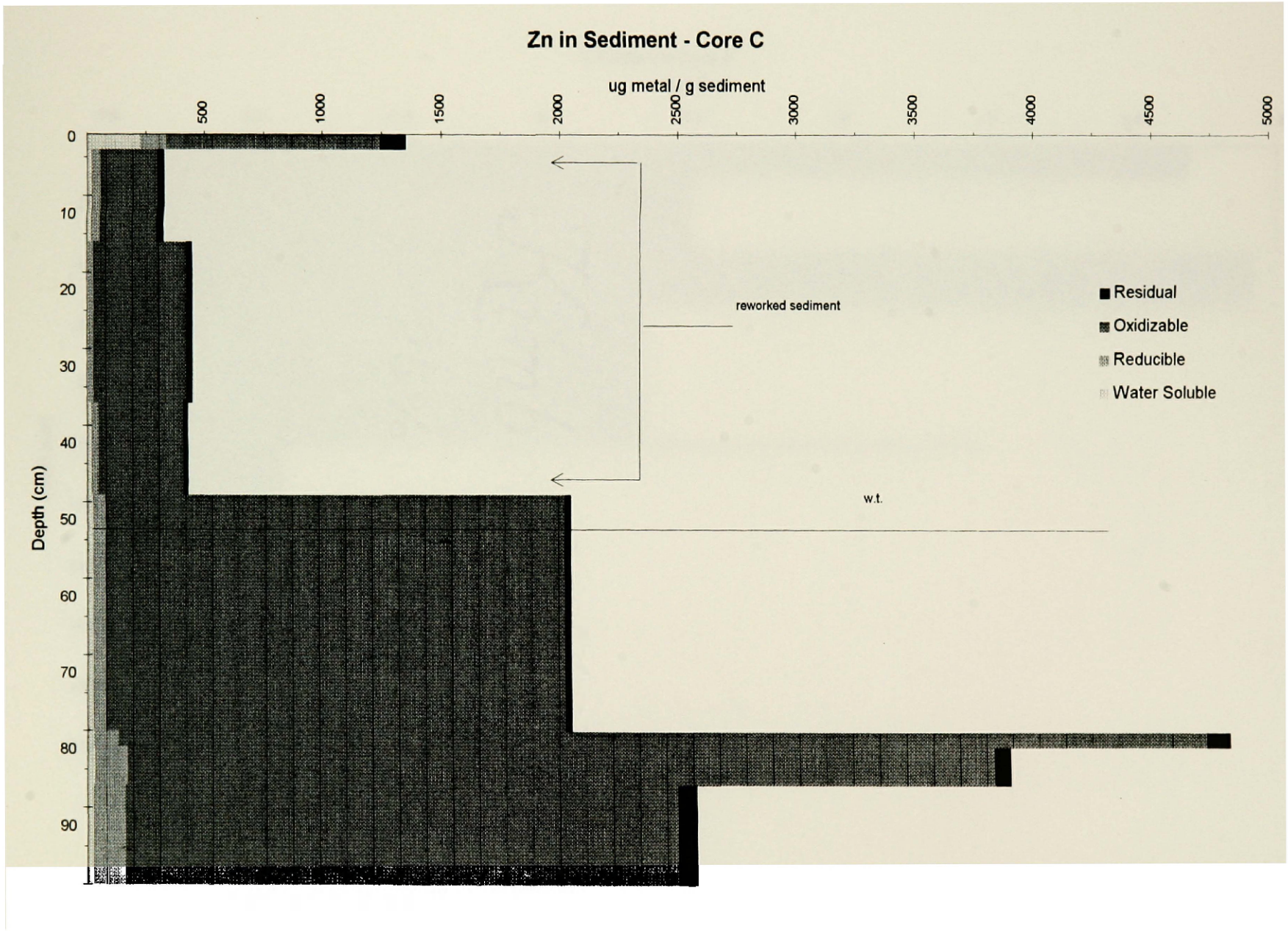

Cd in Sediment - Core C
ug metal / g sediment
0
2
4
6
8
10
12
14
16
18
20
Depth (cm)
0
20
40
60
80
Residual
Oxidizable
Reducible
Water

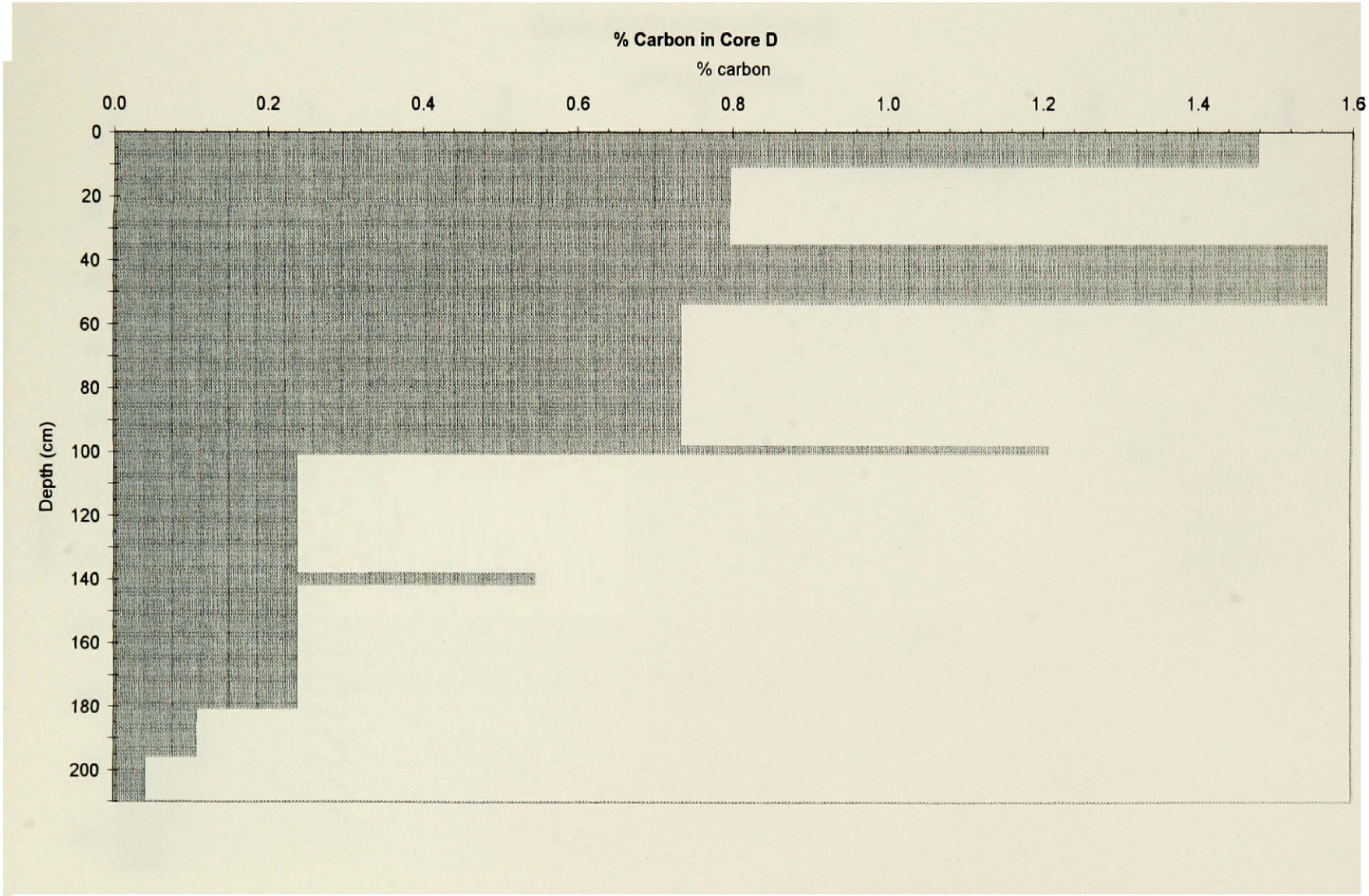

Cu in Sediment - Core C
ug metal / g sediment
0
2000
4000
6000
8000
10000
12000
Depth (cm)
0
20
40
60
80
Residual
Oxidizable
Reducible
Water

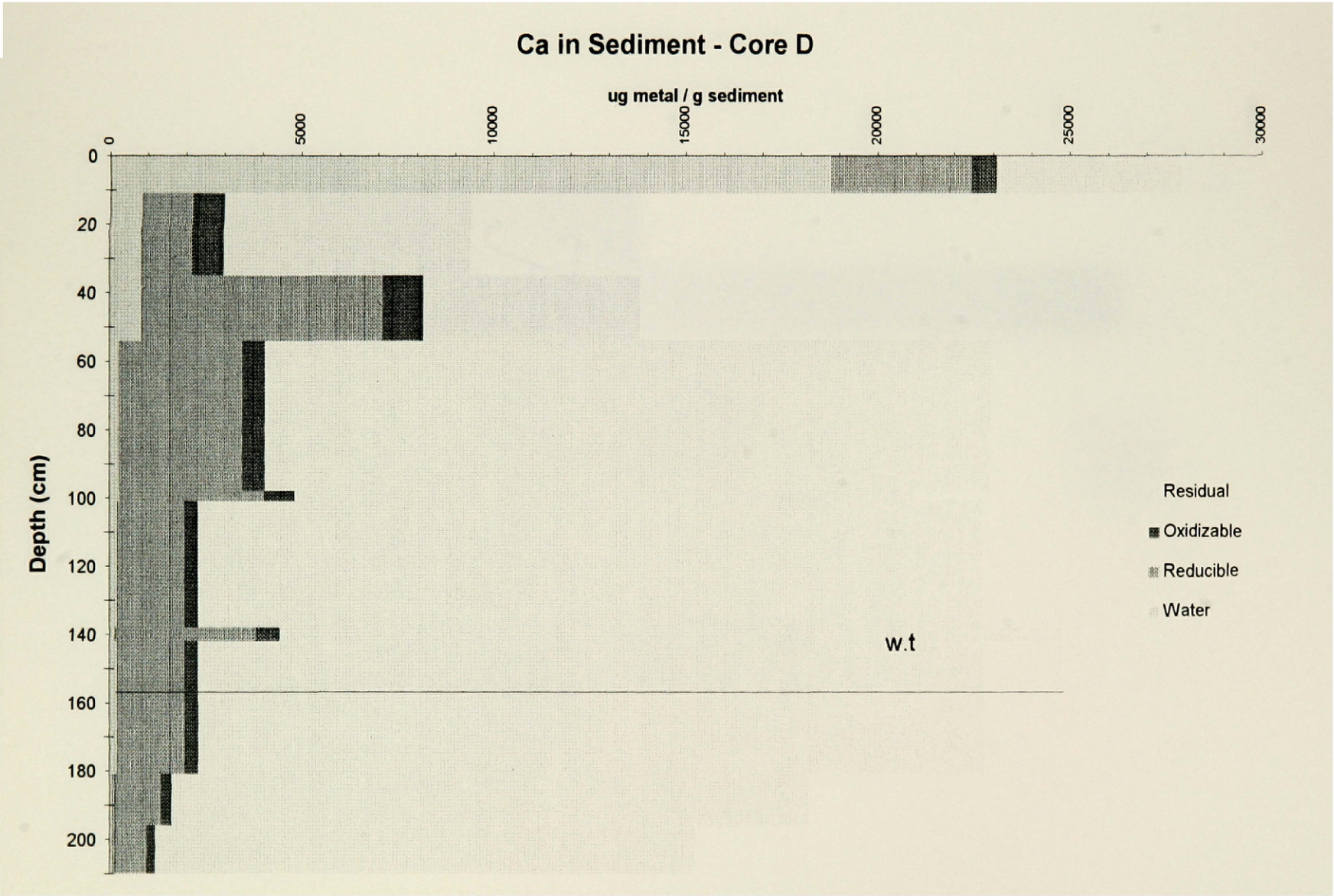

Fe in Sediment - Core C
ug metal / g sediment
Depth (cm)
0
20
40
60
80
0
10000
20000
30000
40000
50000
60000
70000
80000
90000
Residual
Oxidizable
Reducible
Water

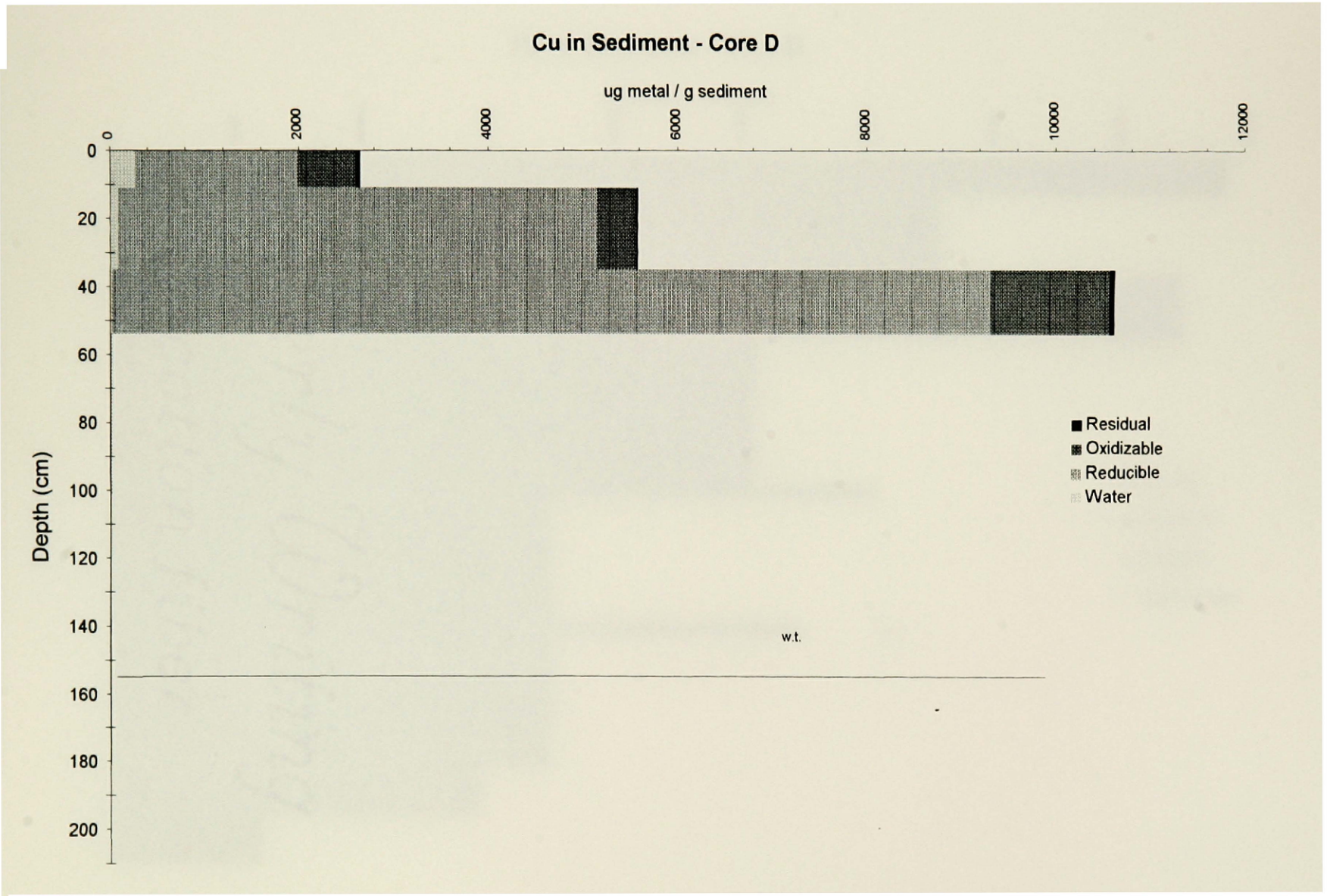

Mn in Sediment - Core C
ug metal / g sediment
0
100
200
300
400
500
600
700
800
900
1000
Depth (cm)
0
20
40
60
80
Residual
Oxidizable
Reducible
Water

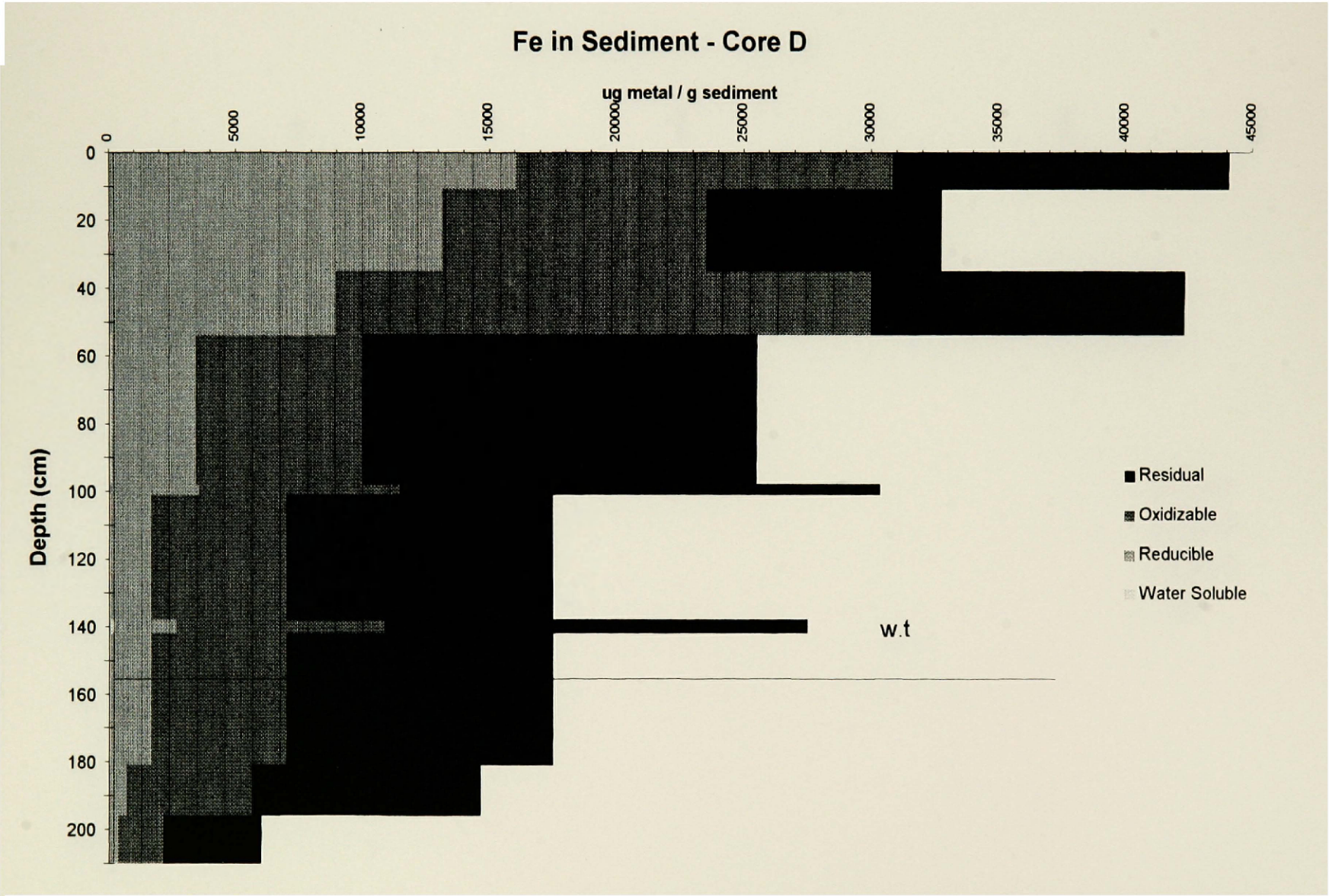

Pb in Sediment - Core C
ug metal / g sediment
0
100
200
300
400
500
600
700
800
900
Depth (cm)
0
20
40
60
80
Residual
Oxidizable
Reducible
Water


Zn in Sediment - Core C
ug metal / g sediment
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
Depth (cm)
0
10
20
30
40
50
60
70
80
90
reworked sediment
w.t.
Residual
Oxidizable
Reducible
Water Soluble

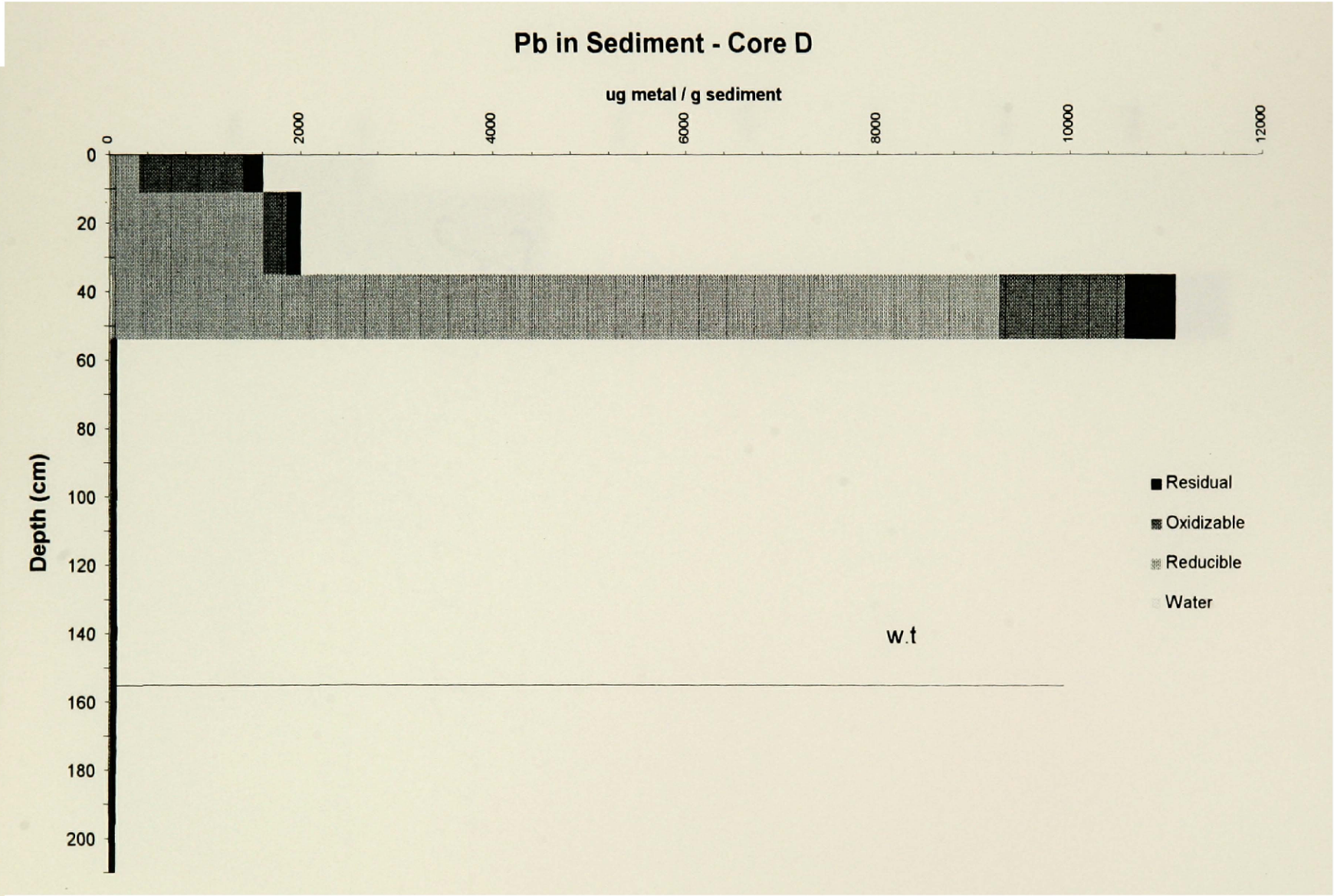

% Carbon in Core D
% carbon
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
Depth (cm)
0
20
40
60
80
100
120
140
160
180
200

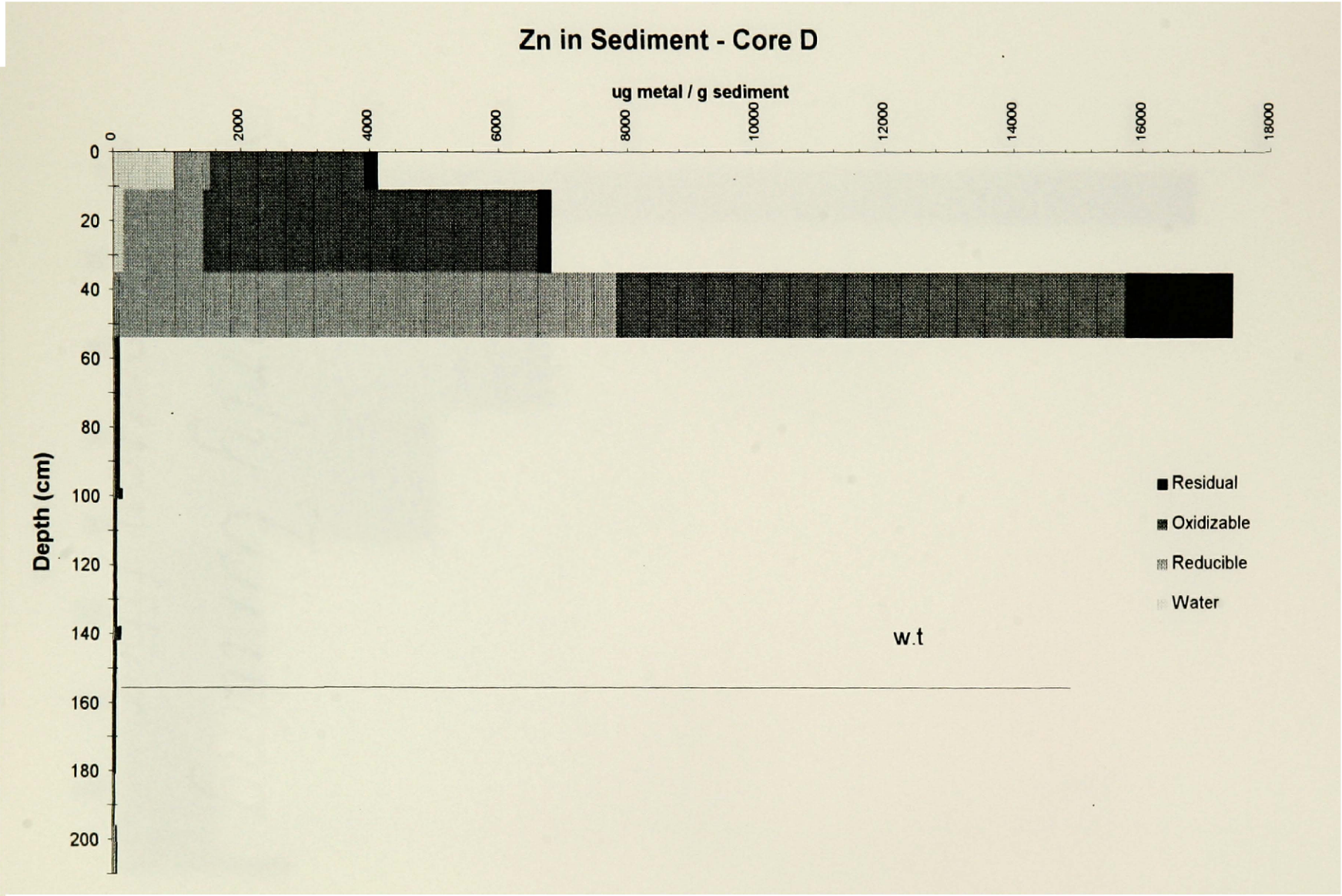

Ca in Sediment - Core D
ug metal / g sediment
0
5000
10000
15000
20000
25000
30000
Depth (cm)
0
20
40
60
80
100
120
140
160
180
200
w.t
Residual
Oxidizable
Reducible
Water

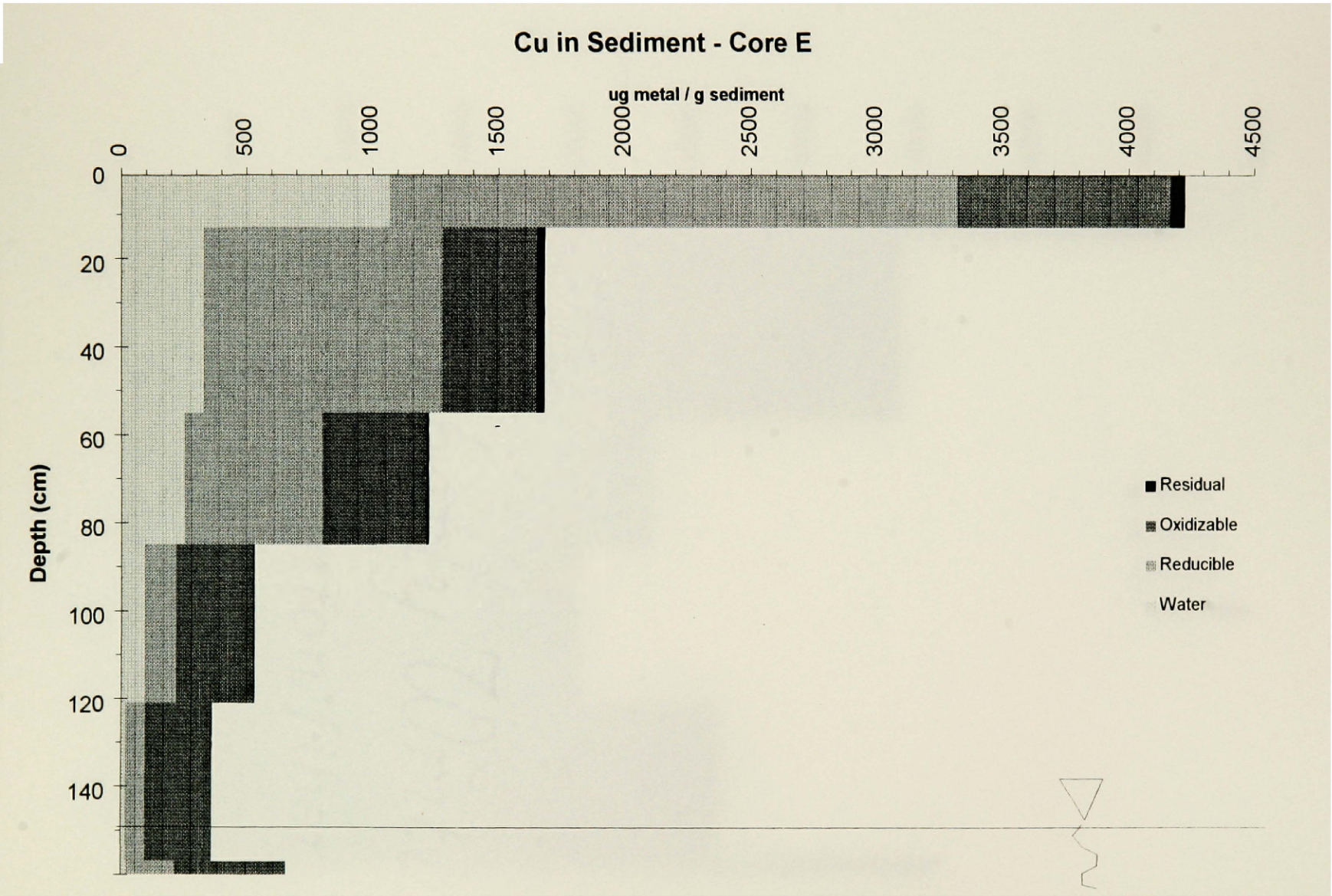

Cu in Sediment - Core D
ug metal / g sediment
0
2000
4000
6000
8000
10000
12000
Depth (cm)
0
20
40
60
80
100
120
140
160
180
200
w.t.
Residual
Oxidizable
Reducible
Water

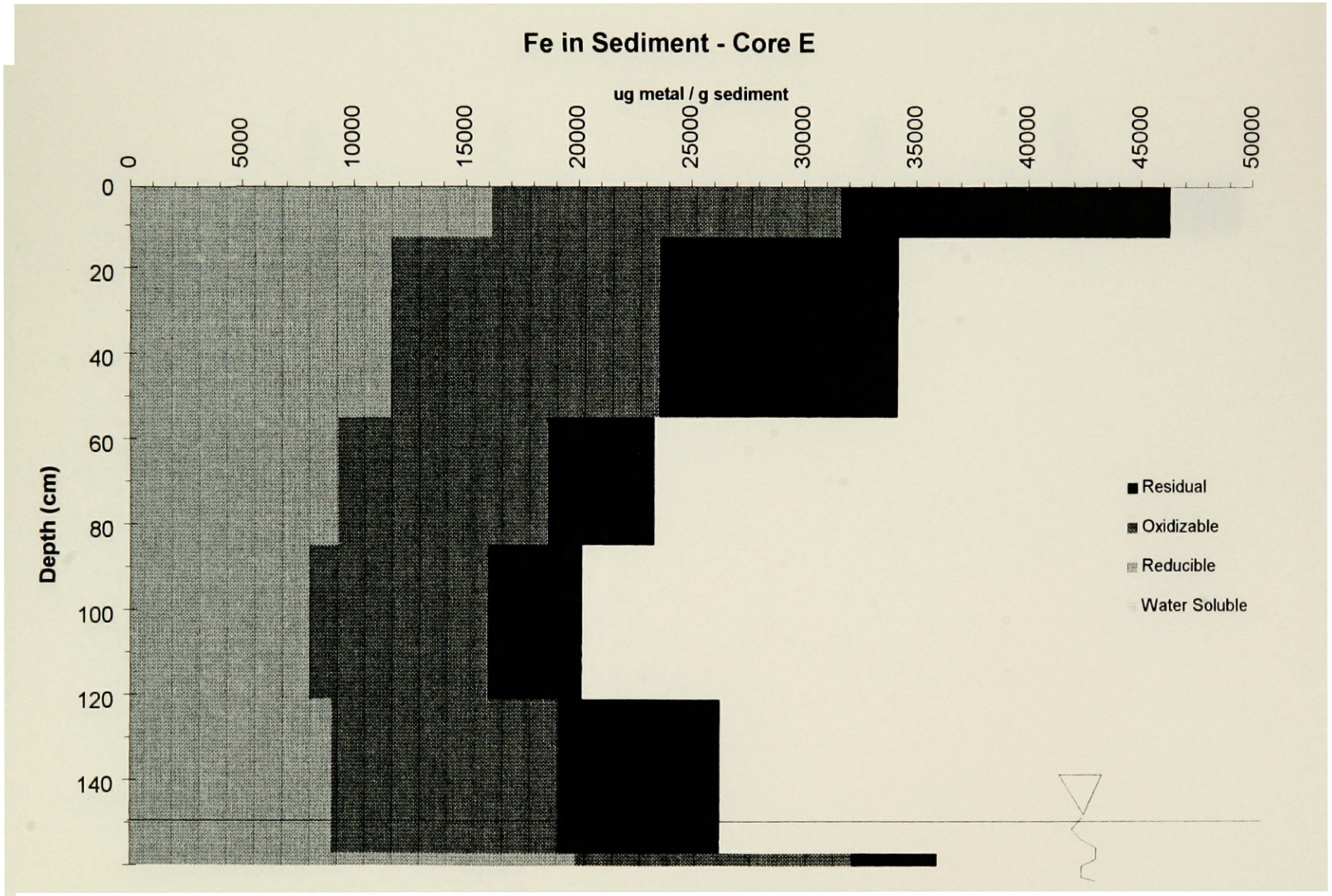

Fe in Sediment - Core D
ug metal / g sediment
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
Depth (cm)
0
20
40
60
80
100
120
140
160
180
200
w.t
Residual
Oxidizable
Reducible
Water Soluble

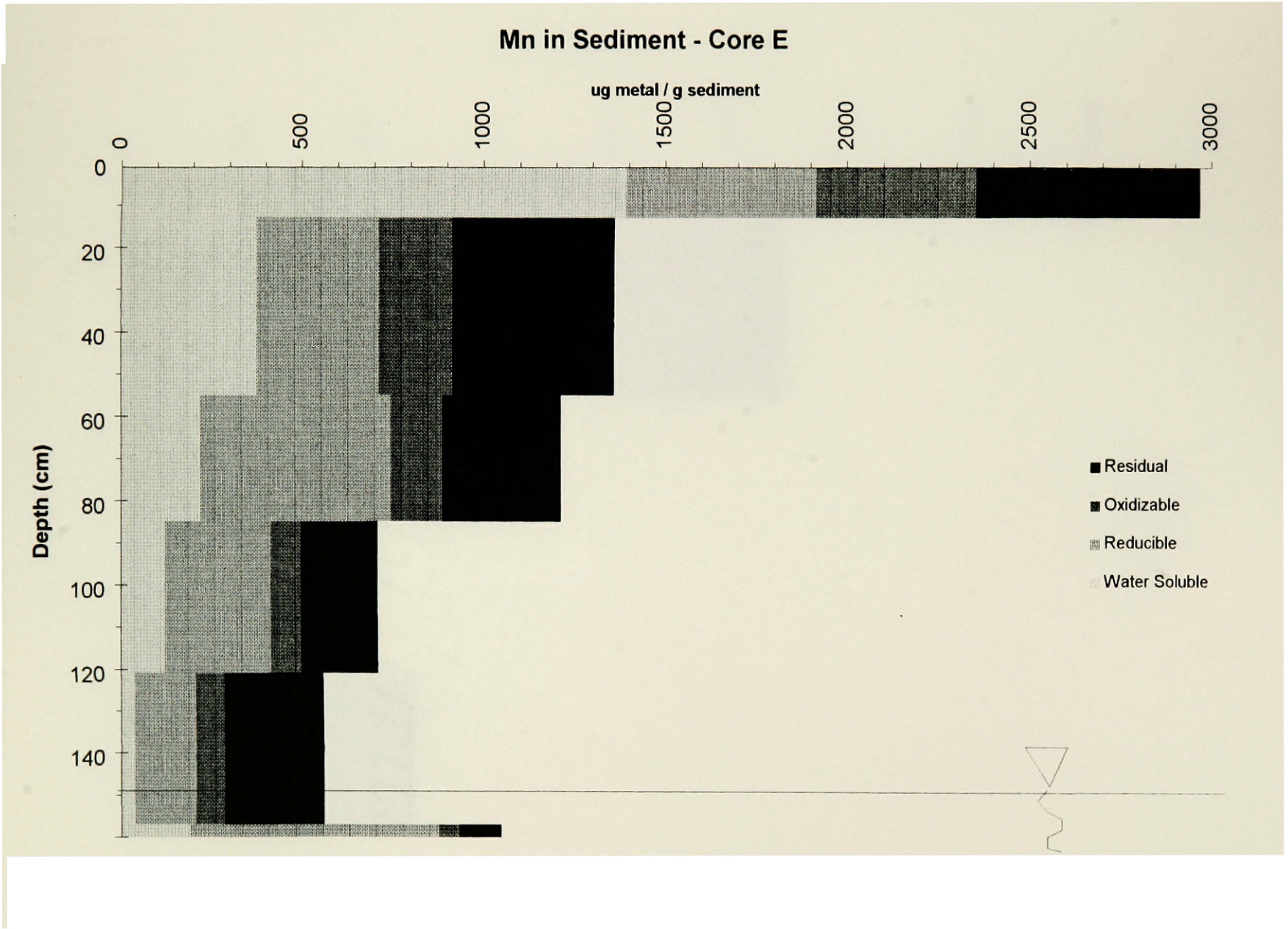

Mn in Sediment - Core D
ug metal / g sediment
0
5000
10000
15000
20000
25000
30000
Depth (cm)
0
20
40
60
80
100
120
140
160
180
200
w.t
Residual
Oxidizable
Reducible
Water

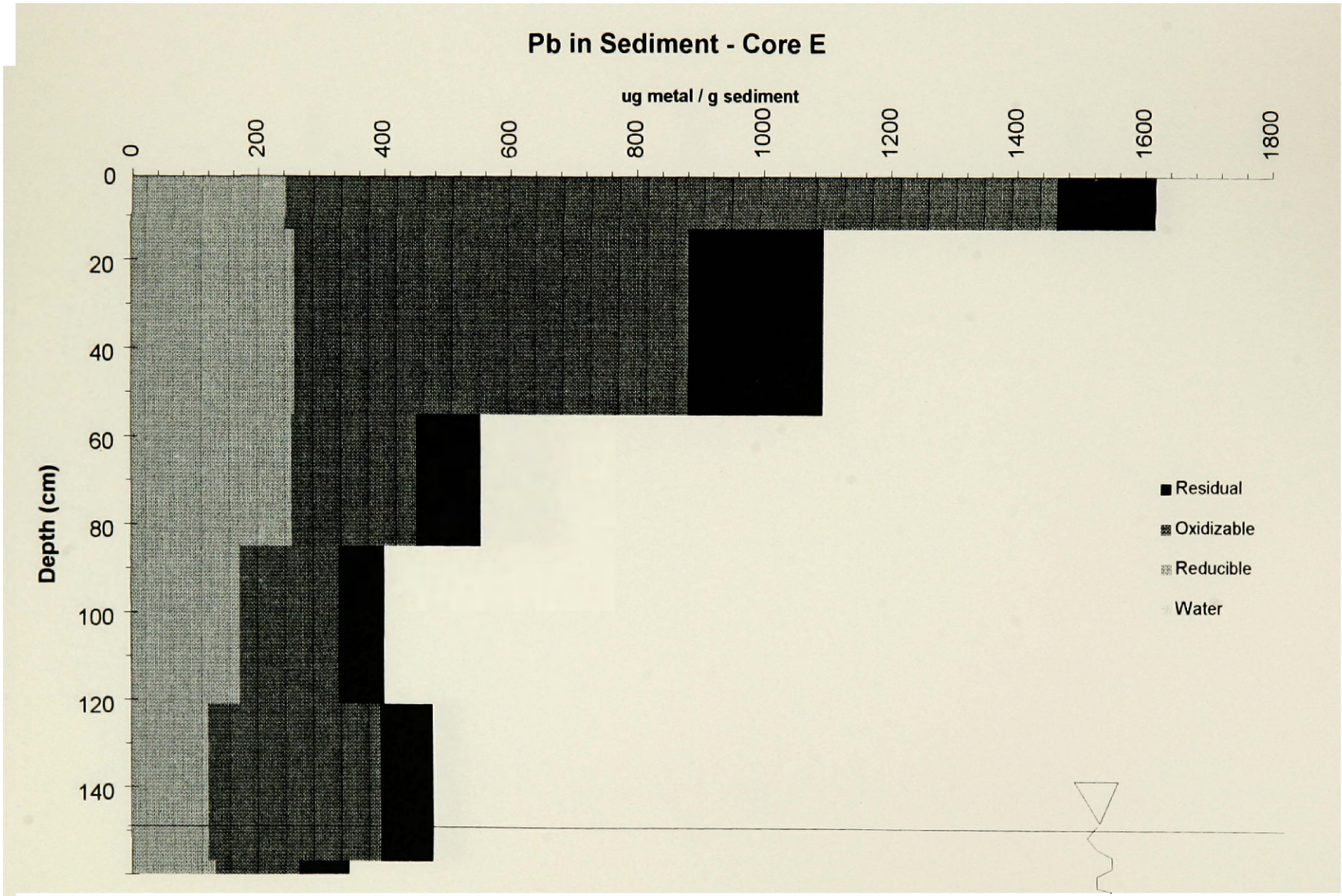

Pb in Sediment - Core D
ug metal / g sediment
0
2000
4000
6000
8000
10000
12000
Depth (cm)
0
20
40
60
80
100
120
140
160
180
200
w.t
Residual
Oxidizable
Reducible
Water

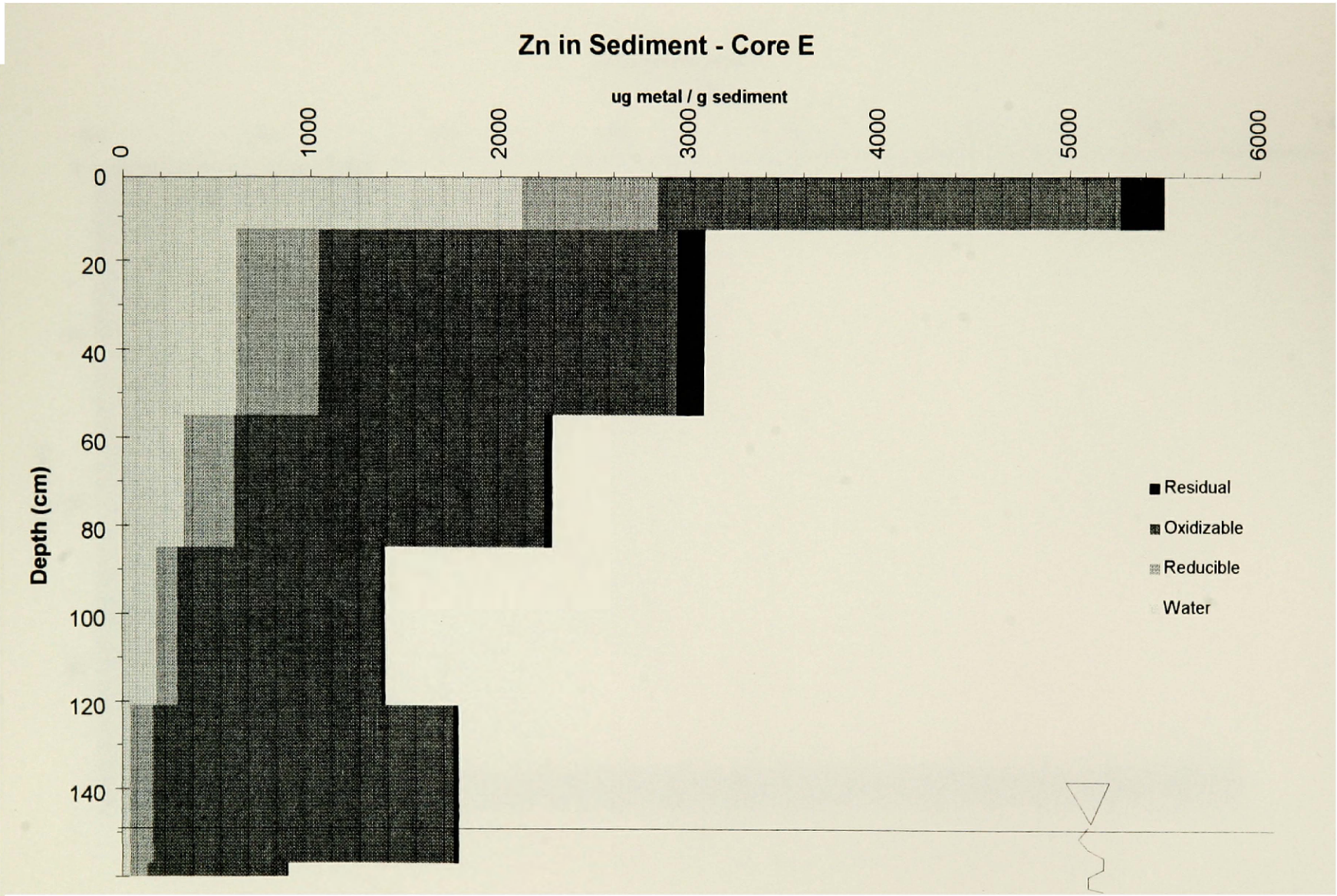

Zn in Sediment - Core D
ug metal / g sediment
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
Depth (cm)
0
20
40
60
80
100
120
140
160
180
200
w.t
Residual
Oxidizable
Reducible
Water

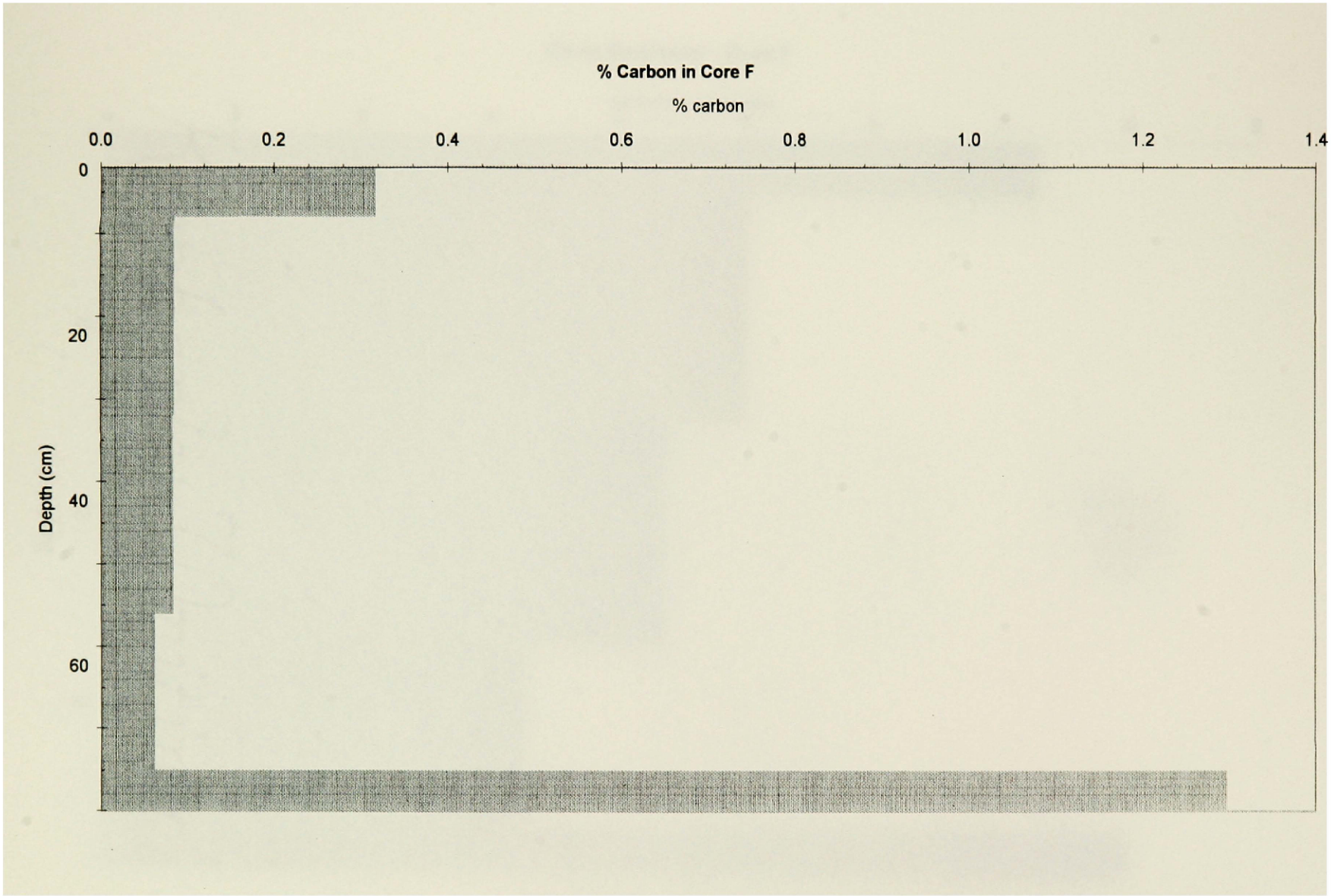

Cu in Sediment - Core E
ug metal / g sediment
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Depth (cm)
0
20
40
60
80
100
120
140
Residual
Oxidizable
Reducible
Water

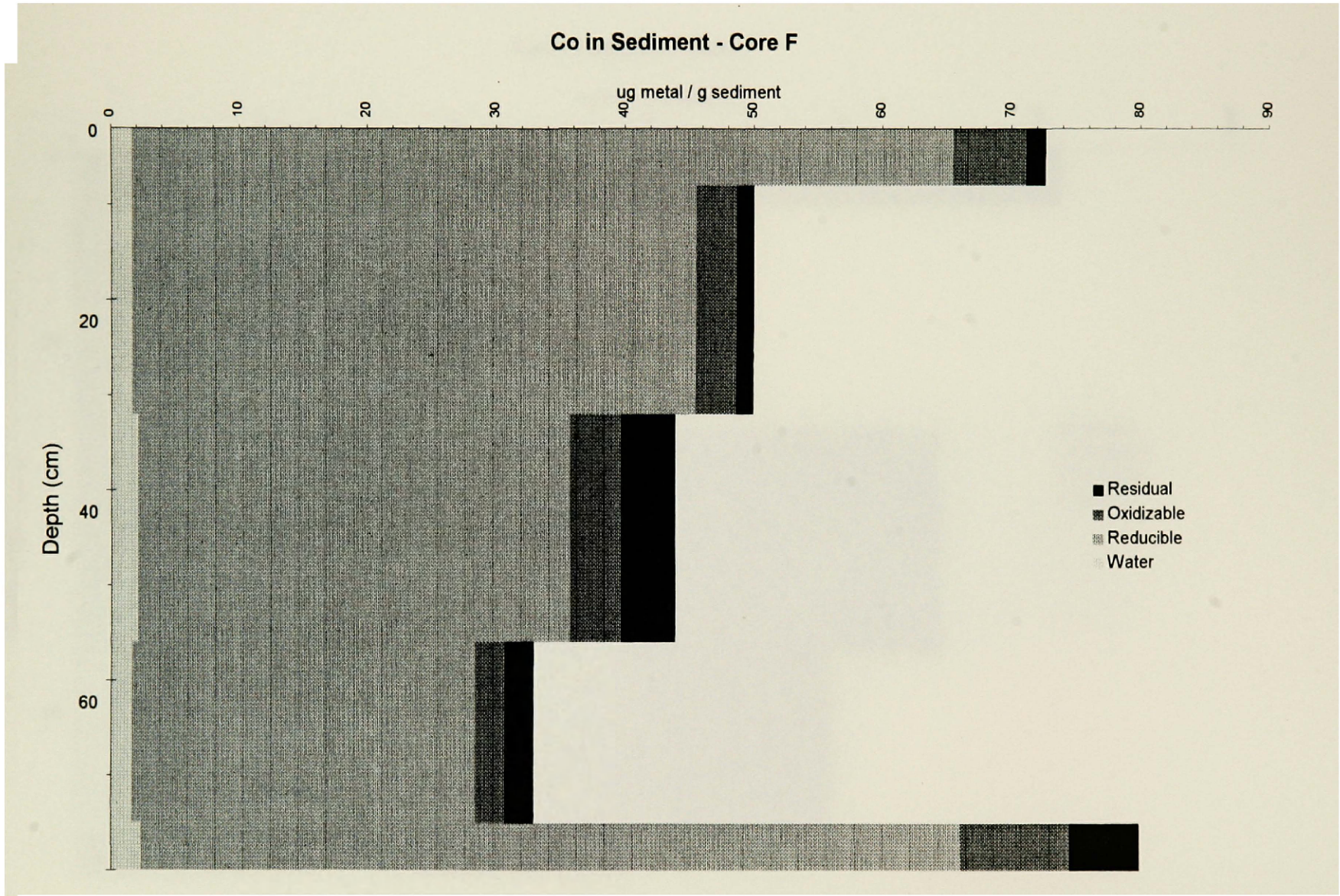

Fe in Sediment - Core E
ug metal / g sediment
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000
Depth (cm)
0
20
40
60
80
100
120
140
Residual
Oxidizable
Reducible
Water Soluble

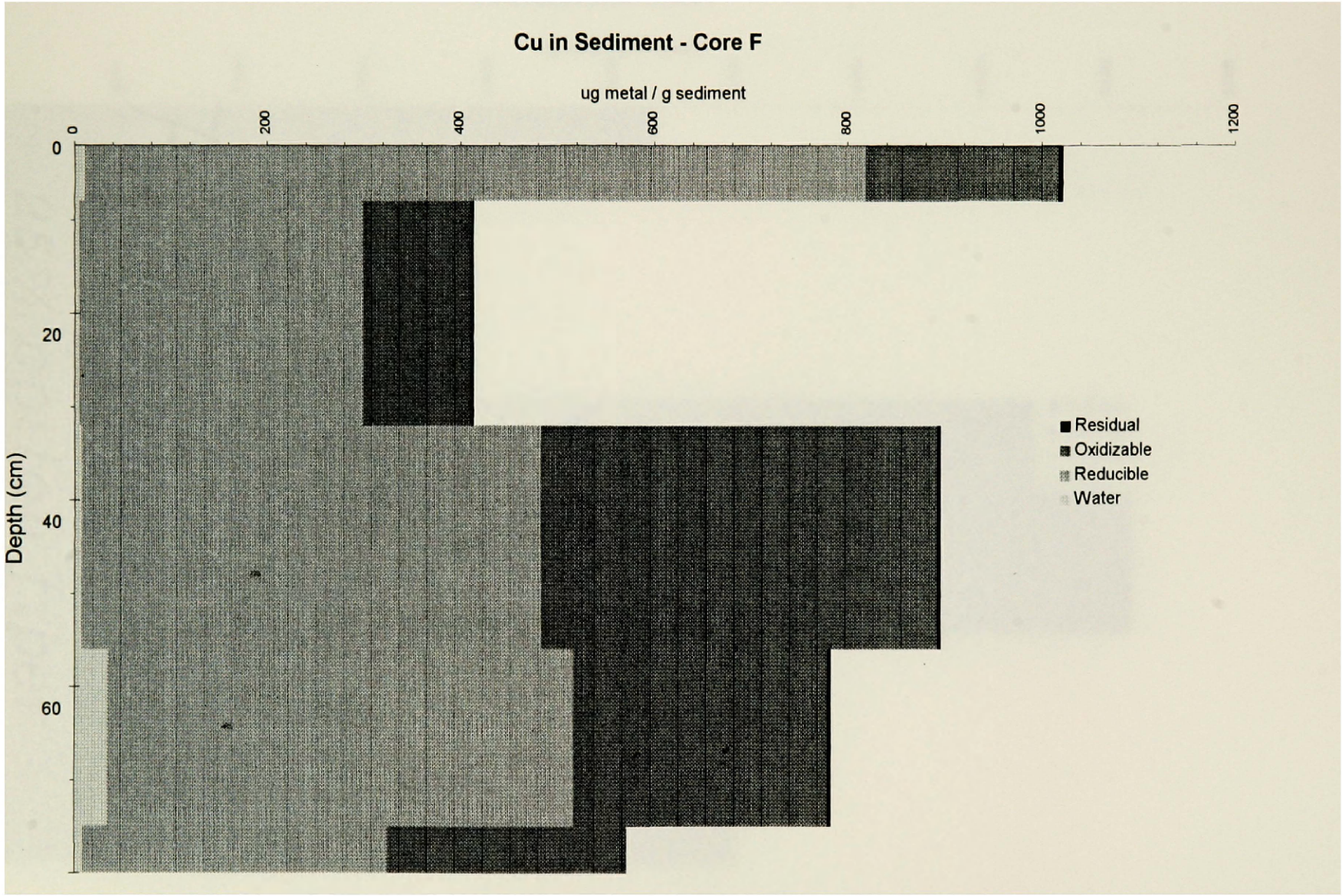

Mn in Sediment - Core E
ug metal / g sediment
0
500
1000
1500
2000
2500
3000
Depth (cm)
0
20
40
60
80
100
120
140
Residual
Oxidizable
Reducible
Water Soluble

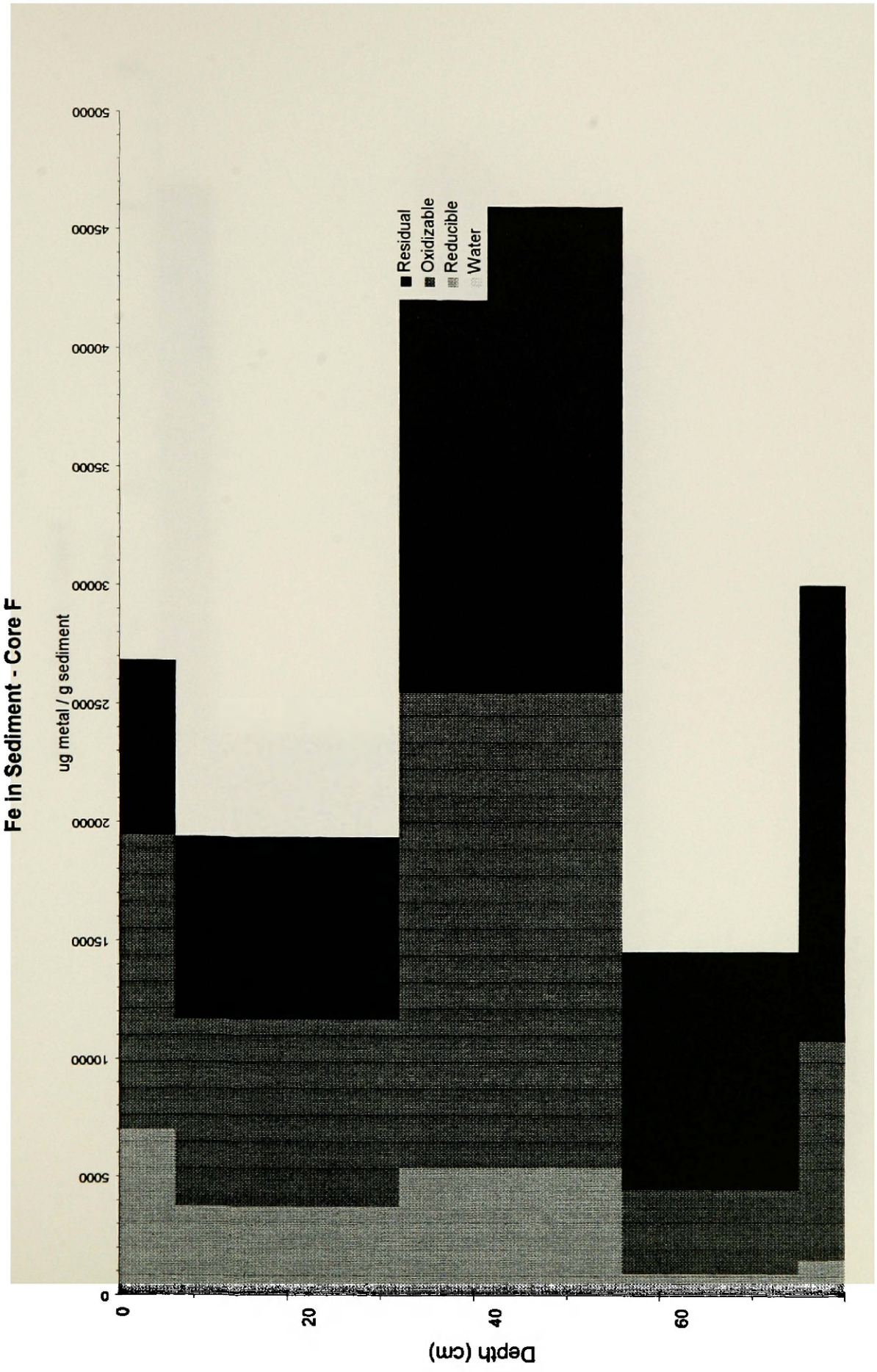

Pb in Sediment - Core E
ug metal / g sediment
0
200
400
600
800
1000
1200
1400
1600
1800
Depth (cm)
0
20
40
60
80
100
120
140
Residual
Oxidizable
Reducible
Water

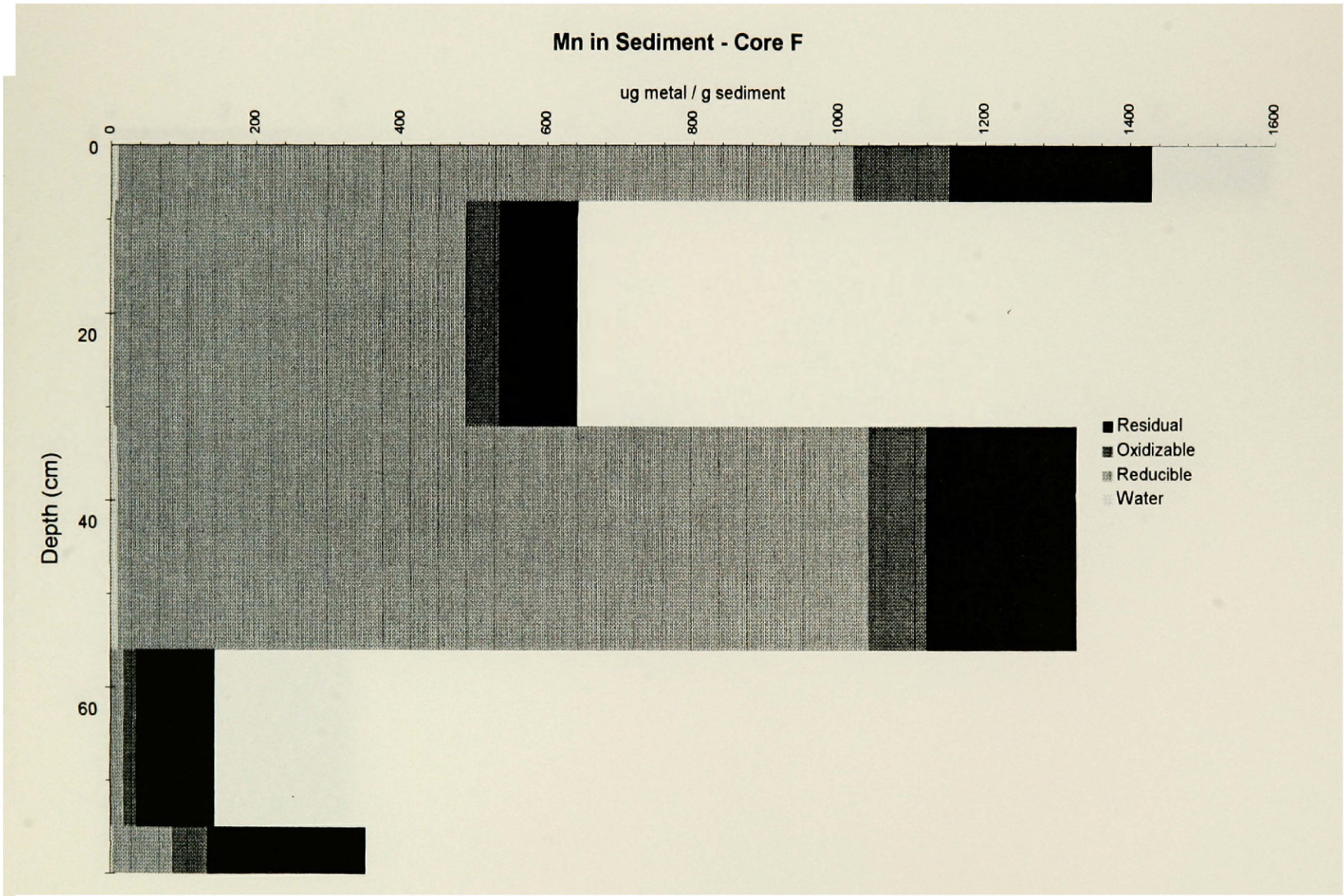

Zn in Sediment - Core E
ug metal / g sediment
0
1000
2000
3000
4000
5000
6000
Depth (cm)
0
20
40
60
80
100
120
140
Residual
Oxidizable
Reducible
Water

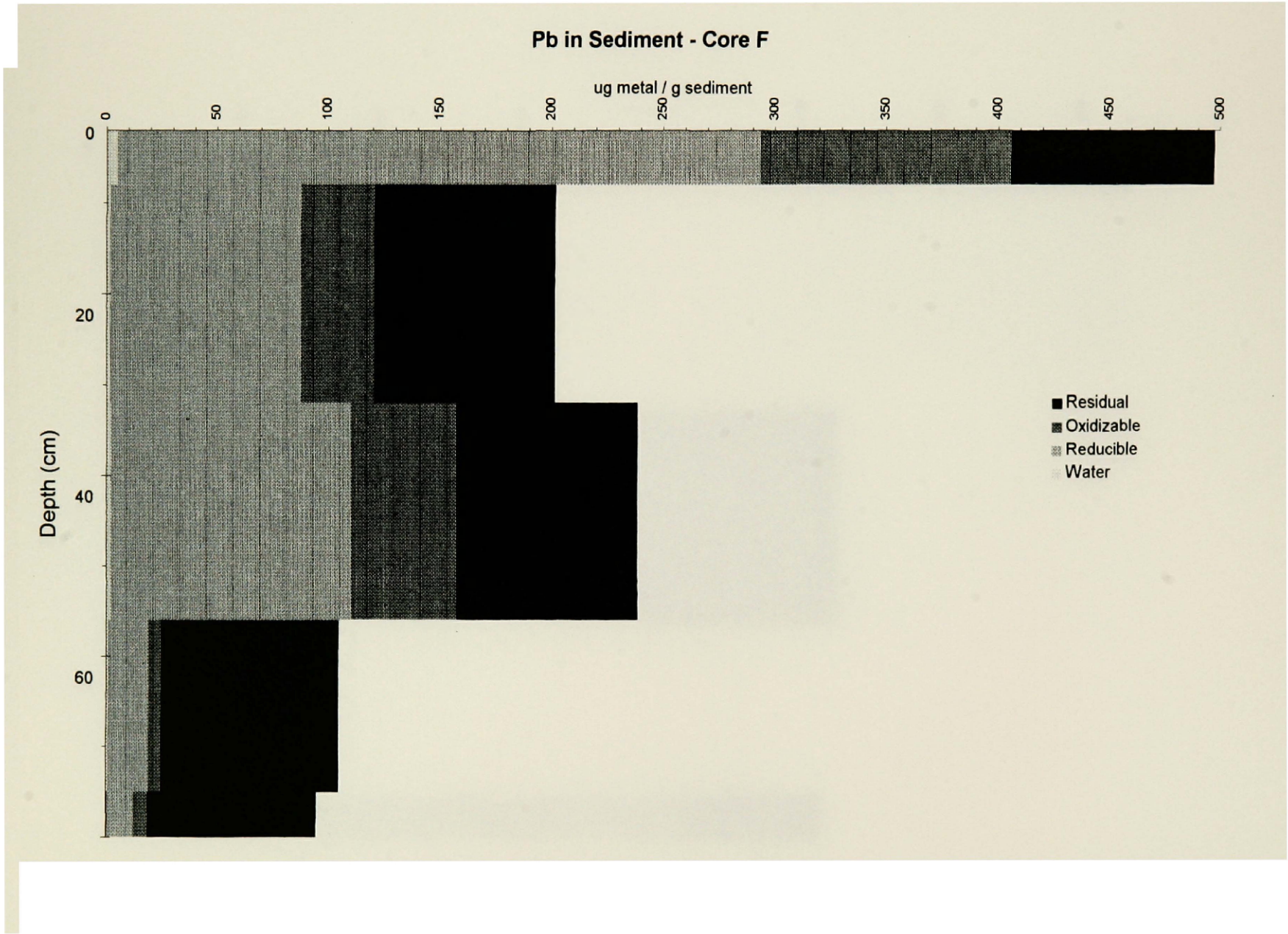

% Carbon in Core F
% carbon
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
0
20
40
60
Depth (cm)

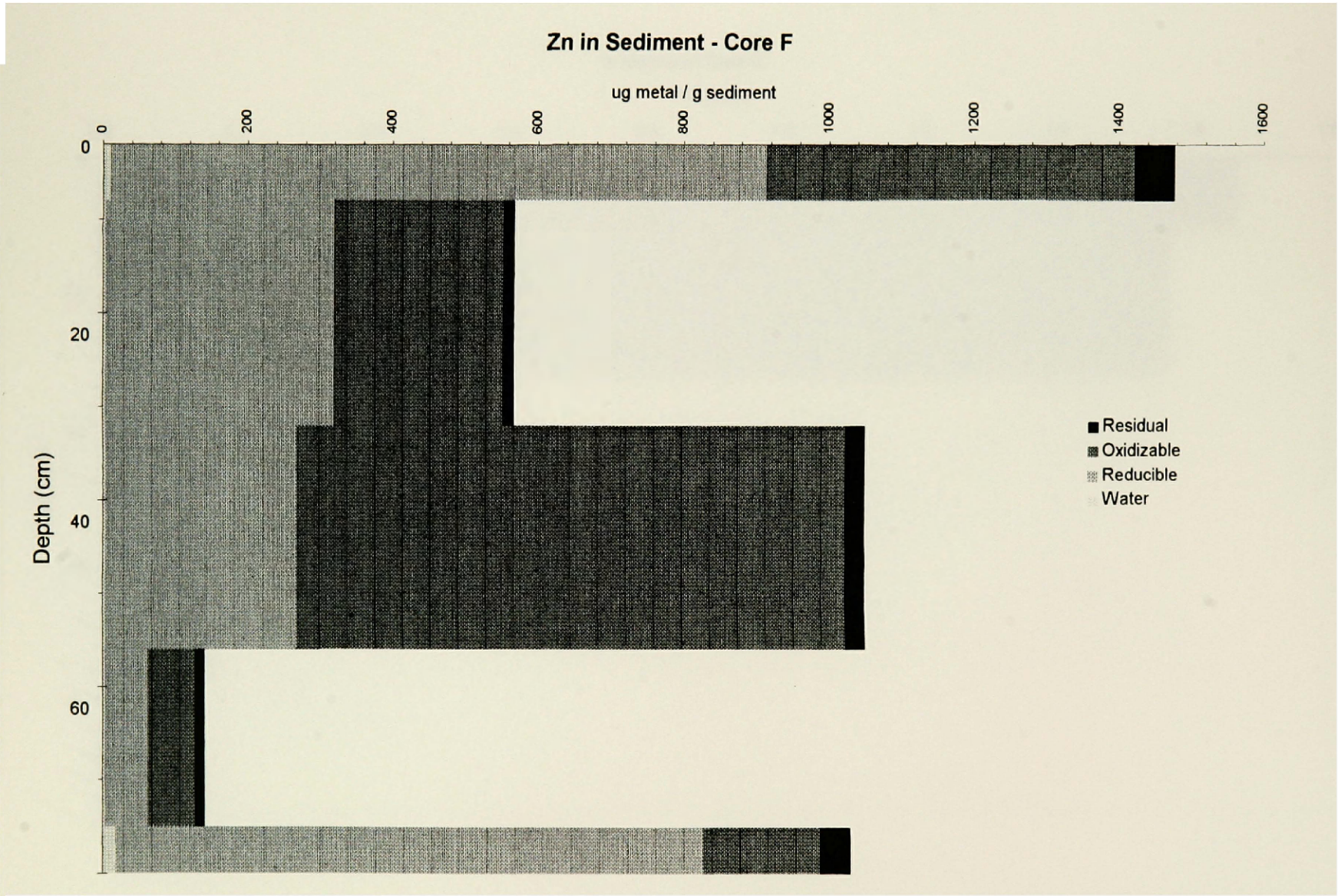

Co in Sediment - Core F
ug metal / g sediment
0
10
20
30
40
50
60
70
80
90
Depth (cm)
0
20
40
60
Residual
Oxidizable
Reducible
Water

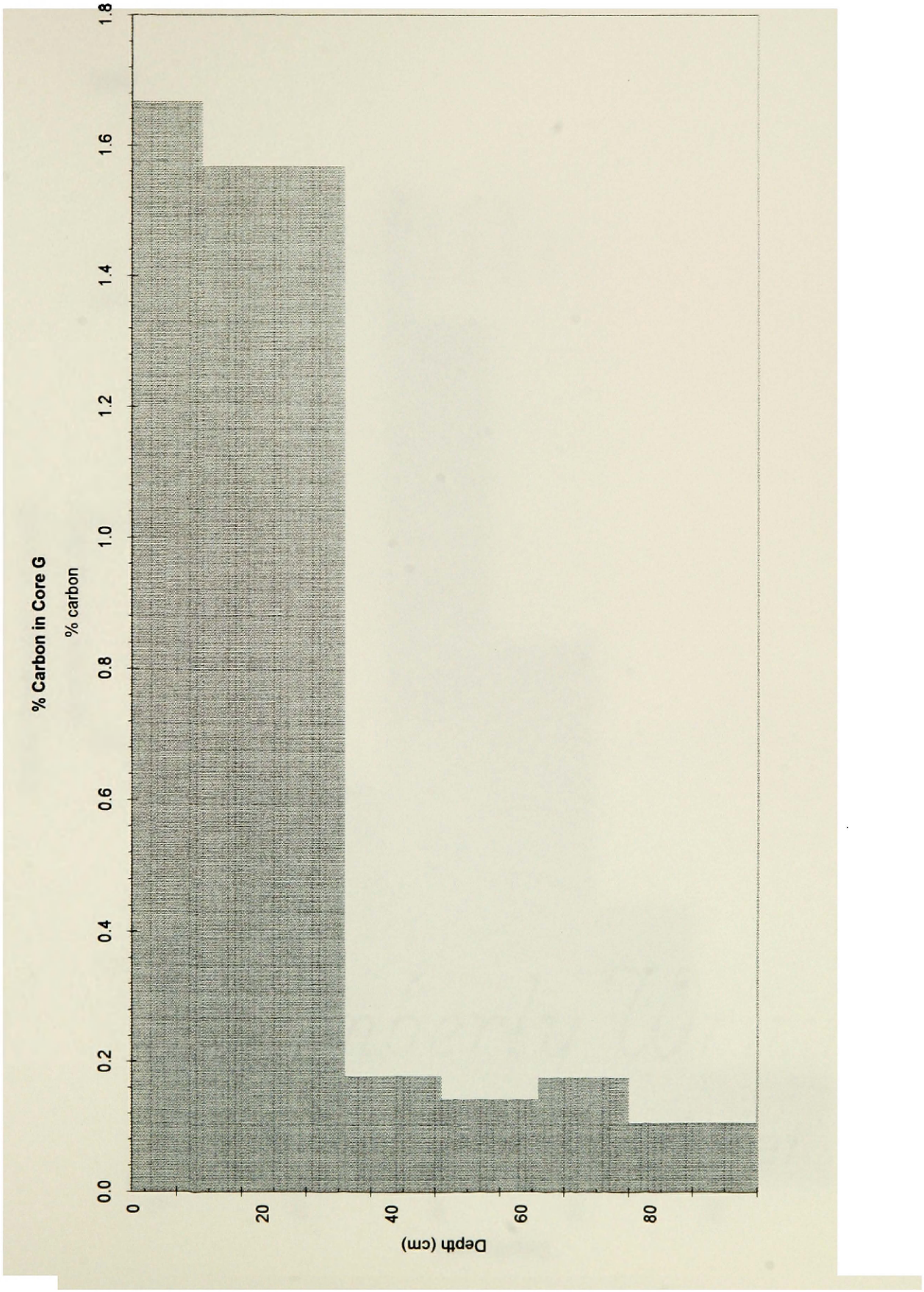

Cu in Sediment - Core F
ug metal / g sediment
0
200
400
600
800
1000
1200
Depth (cm)
0
20
40
60
Residual
Oxidizable
Reducible
Water

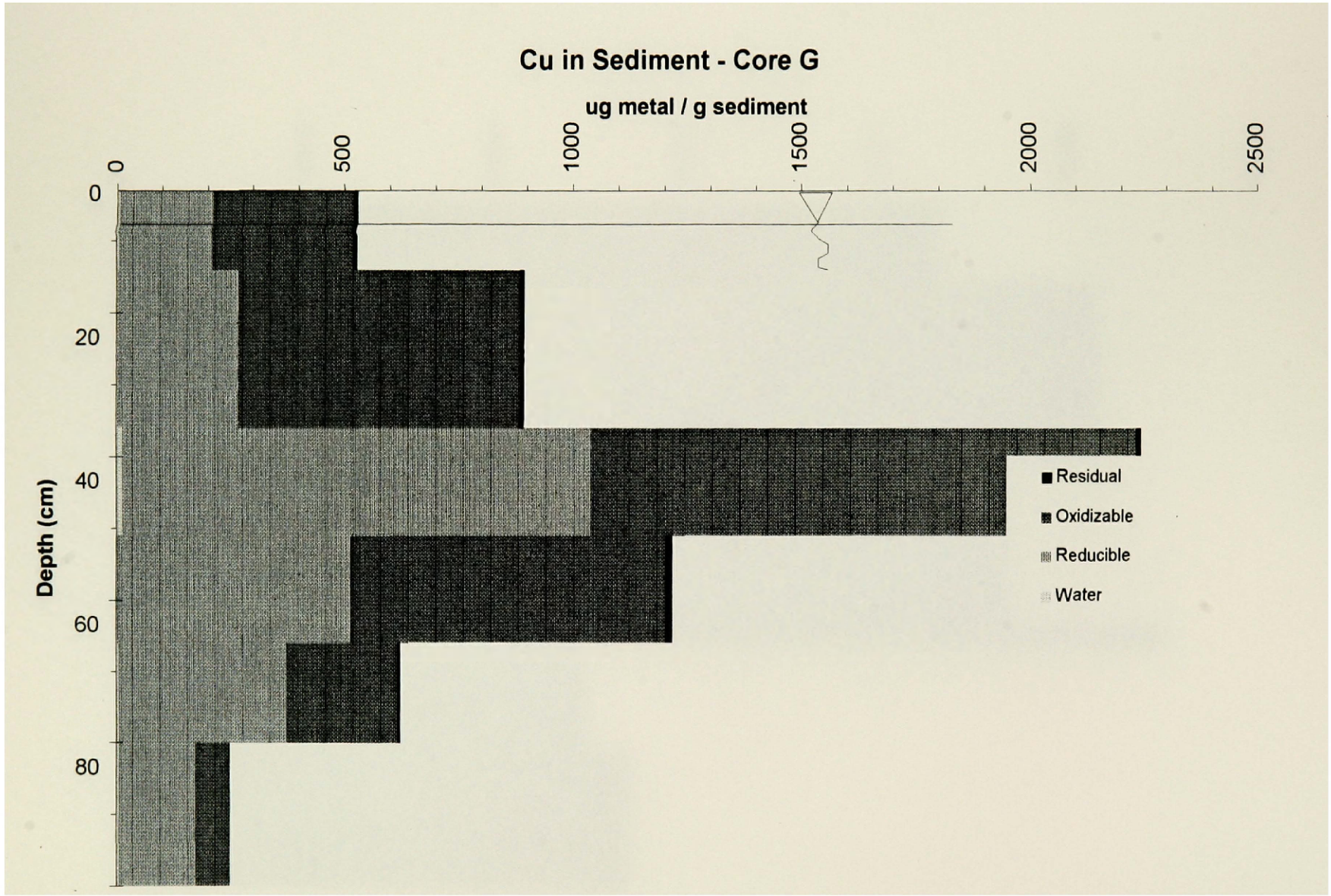

Fe In Sediment - Core F
ug metal / g sediment
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000
Residual
Oxidizable
Reducible
Water
0
20
40
60
Depth (cm)

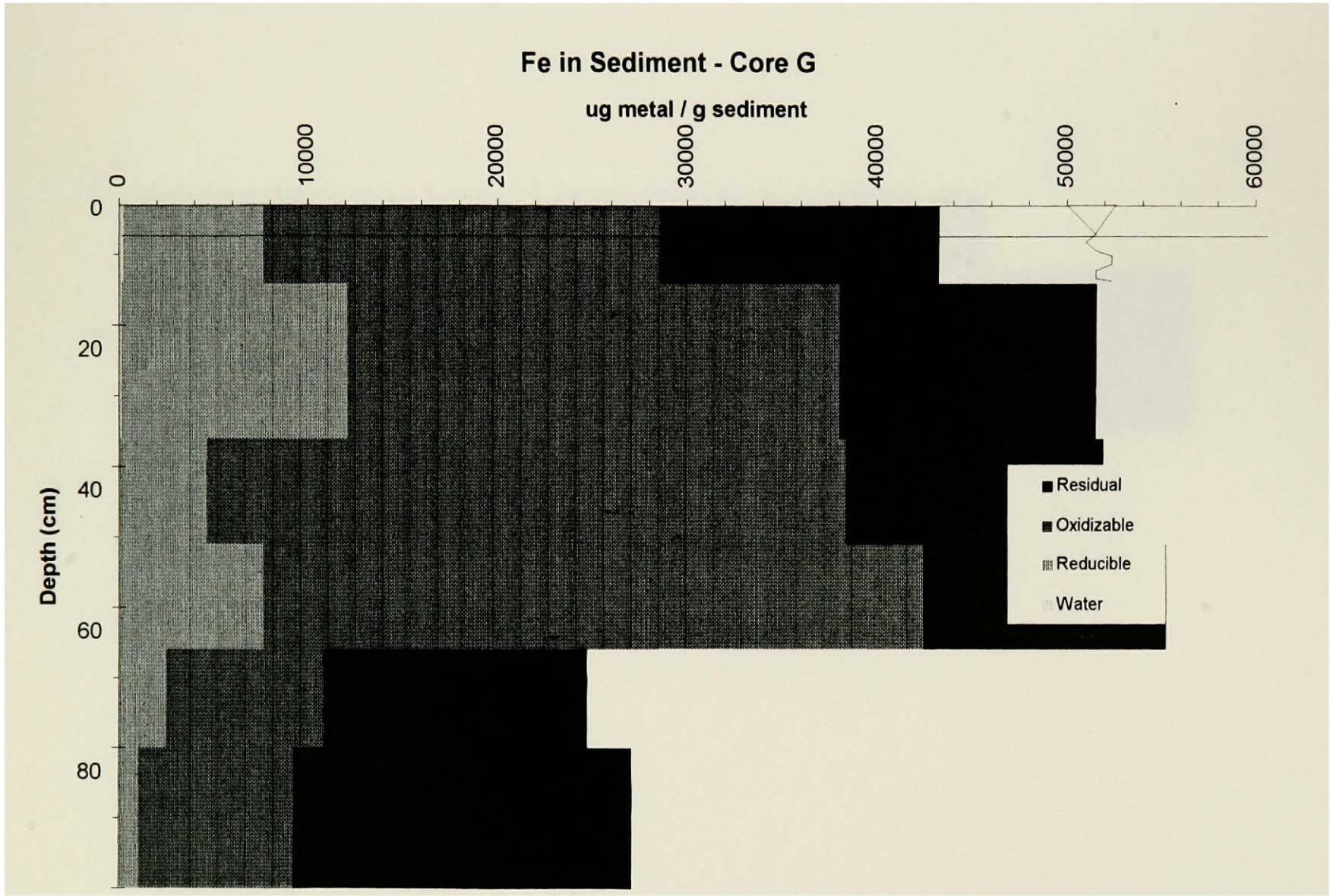

Mn in Sediment - Core F
ug metal / g sediment
0
200
400
600
800
1000
1200
1400
1600
Depth (cm)
0
20
40
60
Residual
Oxidizable
Reducible
Water

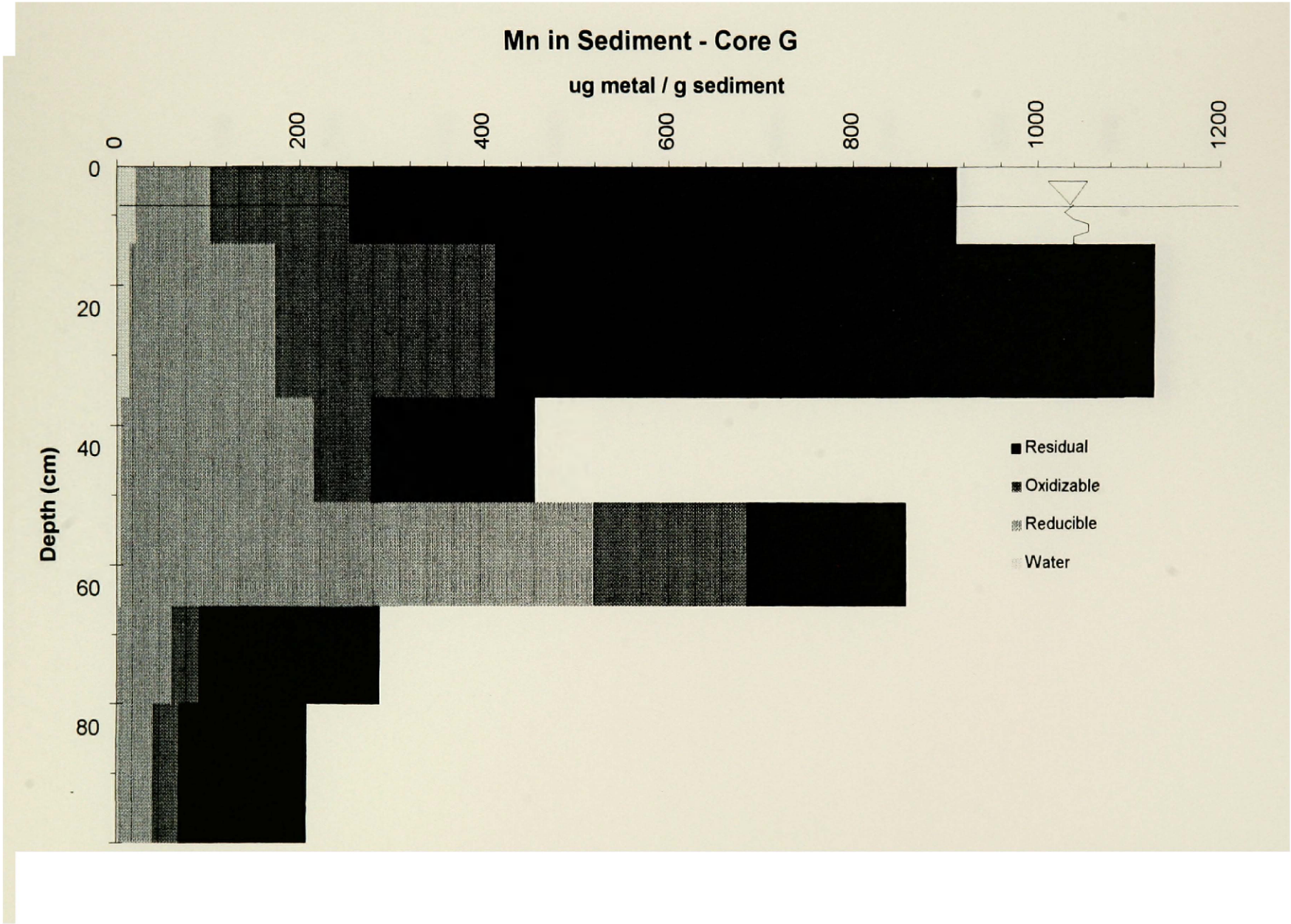

Pb in Sediment - Core F
ug metal / g sediment
0
50
100
150
200
250
300
350
400
450
500
Depth (cm)
0
20
40
60
Residual
Oxidizable
Reducible
Water

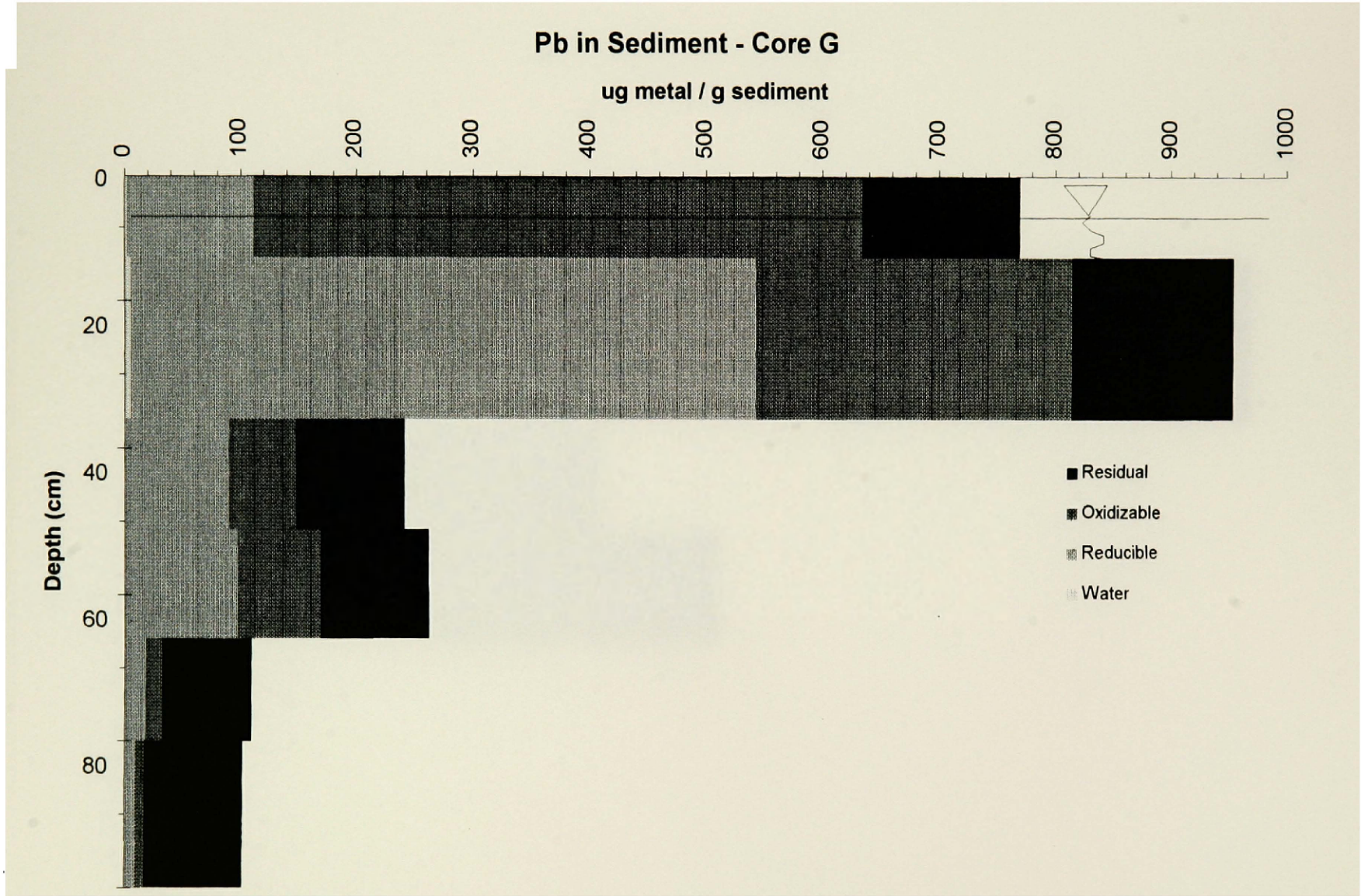

Zn in Sediment - Core F
ug metal / g sediment
0
200
400
600
800
1000
1200
1400
1600
Depth (cm)
0
20
40
60
Residual
Oxidizable
Reducible
Water

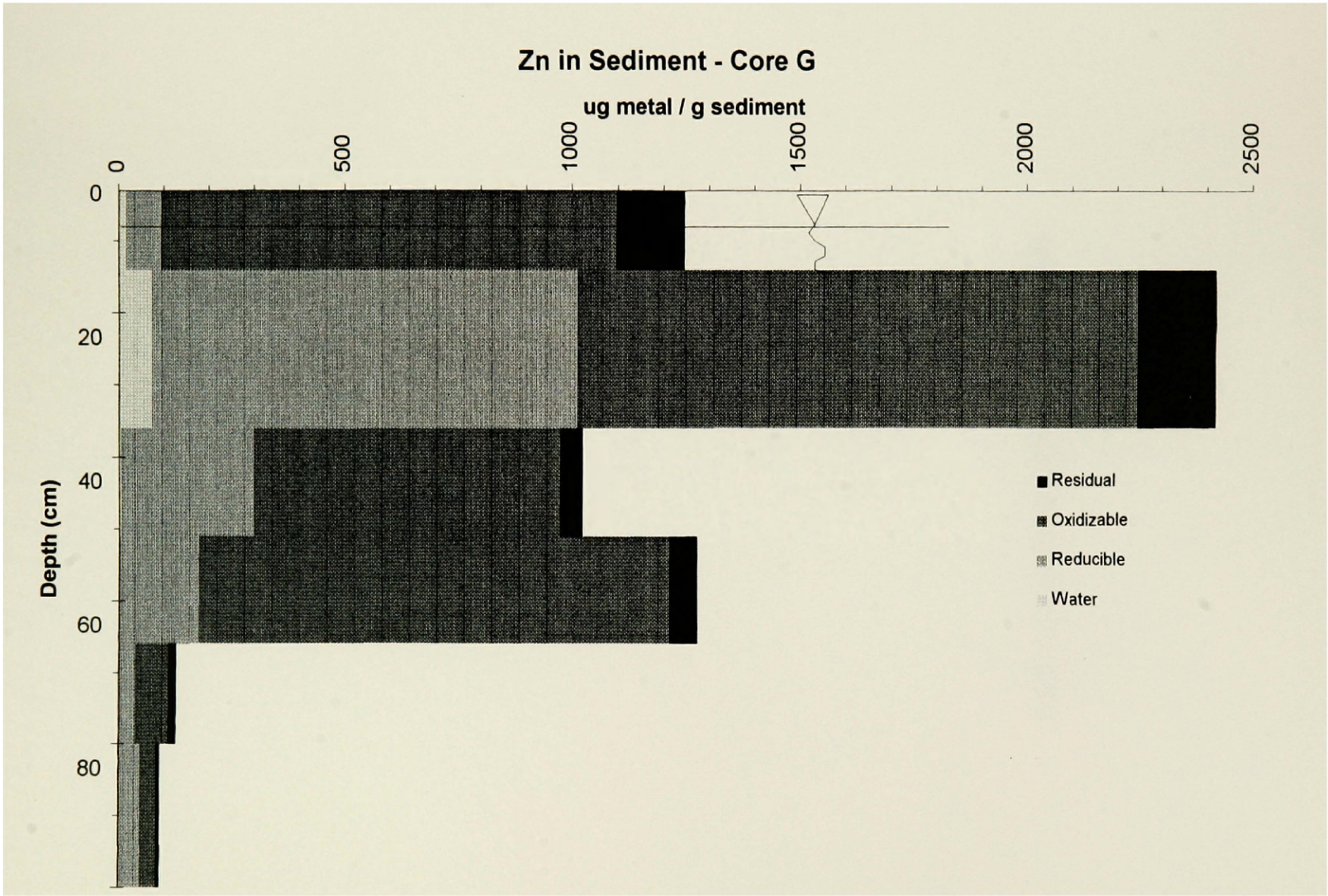

% Carbon in Core G
% carbon
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
0
20
40
60
80
Depth (cm)


Cu in Sediment - Core G
ug metal / g sediment
0
500
1000
1500
2000
2500
Depth (cm)
0
20
40
60
80
Residual
Oxidizable
Reducible
Water


Fe in Sediment - Core G
ug metal / g sediment
0
10000
20000
30000
40000
50000
60000
Depth (cm)
0
20
40
60
80
Residual
Oxidizable
Reducible
Water


Mn in Sediment - Core G
ug metal / g sediment
0
200
400
600
800
1000
1200
Depth (cm)
0
20
40
60
80
Residual
Oxidizable
Reducible
Water


Pb in Sediment - Core G
ug metal / g sediment
0
100
200
300
400
500
600
700
800
900
1000
Depth (cm)
0
20
40
60
80
Residual
Oxidizable
Reducible
Water


Zn in Sediment - Core G
ug metal / g sediment
0
500
1000
1500
2000
2500
Depth (cm)
0
20
40
60
80
Residual
Oxidizable
Reducible
Water

Appendix of Aqueous Chemistry Data

		WATER CHEMISTRY - Miles Crossing -Silver Bow Crk. Research Site - Summer 1994. Concentrations in mg/L. See "key to sample names" for explanation of sample names.									
Instrument detect. limit		*0.06*	*0.06*	*0.15*	*0.009*	*0.009*	*0.04*	*0.04*	*0.09*	*0.02*	*0.016*
Samp name	Date	Al	As	Ca	Cd	Co	Cu	Fe	Mg	Mn	Mo
AL032	5/27/94	245	BIDL	293	5.58	0.936	739	0.59	304	1256	0.056
AL032	6/1/94	202	BIDL	311	5.93	1.02	645	0.86	322	1278	0.051
AL032	6/16/94	213	BIDL	302	5.23	0.820	637	0.62	310	1232	0.043
AL032	7/1/94	211	0.61	305	6.26	1.11	639	0.78	328	1399	0.050
AL032	7/14/94	279	0.31	345	5.60	0.888	696	0.53	310	1306	0.047
AL032 2nd	7/14/94	279	0.32	328	5.30	0.853	694	0.60	293	1226	0.042
AL048	5/27/94	735	BIDL	441	7.36	1.45	1832	6.99	215	1291	0.081
AL048	6/1/94	696	BIDL	441	7.24	1.19	1731	5.73	213	1293	0.043
AL048	6/16/94	751	BIDL	446	7.77	1.48	1833	7.95	229	1387	0.076
AL048	7/14/94	866	0.20	477	8.06	1.38	1963	8.12	258	1551	0.066
AL048 2nd	7/14/94	910	0.70	471	8.33	1.39	2084	8.57	260	1548	0.059
AL048	7/28/94	783	BIDL	436	6.91	1.28	1855	7.97	241	1496	0.063
AL085	5/27/94	720	BIDL	442	4.94	0.724	951	20.5	184	556	0.082
AL085 2nd	5/27/94	662	BIDL	373	5.20	0.788	937	21.3	155	500	0.081
AL085	6/1/94	658	BIDL	392	4.71	0.660	874	17.6	160	504	0.033
AL085	6/16/94	606	BIDL	384	4.35	0.614	827	18.6	152	477	0.042
AL085	7/1/94	558	BIDL	347	4.53	0.639	790	22.5	146	517	0.044
AL085	7/14/94	663	0.068	390	4.63	0.643	869	27.6	157	504	0.055
AL085 2nd	7/14/94	666	0.24	415	4.61	0.648	895	30.9	158	520	0.066
AL085	7/28/94	633	BIDL	374	4.31	0.650	869	32.8	151	508	0.057
AL085	9/19/94	686	BIDL	417	5.13	0.794	904	68.1	159	539	0.115
AL125	5/23/94	38	BIDL	40.9	0.281	0.031	39.2	32.0	10.7	20.5	0.046
AL125	5/27/94	18	BIDL	25.4	0.130	0.012	21.7	16.5	7.08	9.69	0.020
AL125 2nd	5/27/94	17	BIDL	26.7	0.129	0.012	21.3	16.5	7.55	9.50	0.022
AL125	6/1/94	16	BIDL	31.1	0.130	0.012	17.8	15.6	8.43	9.47	0.022
AL125	6/16/94	17	BIDL	33.0	0.137	0.012	19.0	16.9	8.98	10.0	0.024
AL125	7/1/94	15	BIDL	32.1	0.115	0.011	15.8	15.3	8.72	8.78	0.019
AL125 FD	7/1/94	14	BIDL	32.6	0.116	0.012	15.6	15.3	8.77	8.77	0.021
AL125	7/14/94	18	BIDL	38.4	0.143	0.014	19.0	19.3	10.4	11.1	0.026
AL125 2nd	7/14/94	24	BIDL	48.3	0.191	0.019	23.5	23.4	13.4	14.6	0.036
AL125	7/28/94	24	BIDL	46.6	0.189	0.018	24.4	22.9	12.5	15.1	0.033
AL125	9/19/94	27	BIDL	53.3	0.234	0.024	27.8	27.8	13.8	18.2	0.041
A10	7/28/94	1.4	BIDL	146	0.075	0.014	8.62	28.2	43.7	45.8	0.046
B10 2.7'	7/28/94	BIDL	BIDL	41.1	0.012	BIDL	0.175	1.48	9.91	1.54	BIDL
B10 4.7'	7/28/94	0.19	BIDL	46.2	0.022	BIDL	0.290	0.38	10.4	1.08	BIDL
B10 7.5'	7/28/94	4.6	BIDL	53.8	0.229	0.076	5.02	112	12.8	8.56	0.160
B40	5/27/94	18.3	BIDL	59.5	0.079	0.056	11.7	166	16.6	12.9	0.233
B50 6.25'	5/27/94	6.3	BIDL	117	0.787	0.059	1.391	83.4	30.7	22.9	0.117
BL032	6/1/94	141	BIDL	522	3.16	0.557	976	0.48	97.9	582	0.018
BL032	6/16/94	107	BIDL	457	2.93	0.510	786	0.41	88.4	480	0.020
BL032	7/1/94	83	0.060	449	2.74	0.474	654	0.30	78.8	495	BIDL
BL032	7/14/94	116	BIDL	472	2.84	0.487	834	0.32	87.3	472	0.024

		WATER CHEMISTRY - Miles Crossing -Silver Bow Crk. Research Site - Summer 1994. Concentrations in mg/L. See "key to sample names" for explanation of sample names.										
Instrument detect. limit		*0.35*	*0.023*	*0.095*	*0.09*	*0.008*	*0.02*	*0.095*				
Samp name	Date	Na	Ni	Pb	Si	Sr	Ti	Zn	SO_4	pH	T (C)	dO_2
AL032	5/27/94	310	0.950	BIDL	43.3	0.605	0.09	1583		4.0	15.2	
AL032	6/1/94	290	0.866	BIDL	44.0	0.579	0.07	1666	8780	3.8	12.4	5.6
AL032	6/16/94	293	0.813	BIDL	41.7	0.532	0.06	1583	8430	3.7	9.1	4.4
AL032	7/1/94	422	0.865	BIDL	44.5	0.669	0.07	1438	9013	3.6	20.6	
AL032	7/14/94	352	0.892	BIDL	52.8	0.572	0.09	1758	9098	3.6	20.4	
AL032 2nd	7/14/94	341	0.868	BIDL	52.0	0.525	0.09	1673				
AL048	5/27/94	84.2	1.16	BIDL	51.5	0.432	0.13	2266		3.4		
AL048	6/1/94	77.2	1.11	BIDL	57.1	0.449	0.10	2220		3.9	12.3	5.2
AL048	6/16/94	107	1.17	BIDL	58.4	0.456	0.10	2329	13917	3.3	11.4	5.4
AL048	7/14/94	92.6	1.32	BIDL	69.3	0.490	0.12	2703	15230	3.1	19.0	
AL048 2nd	7/14/94	93.4	1.35	BIDL	69.3	0.483	0.13	2736		3.2		
AL048	7/28/94	111	1.21	BIDL	66.3	0.509	0.12	2516	15182	3.2	19.5	
AL085	5/27/94	133	0.704	0.330	49.5	1.140	0.16	1781	9246	3.3	10.5	6.9
AL085 2nd	5/27/94	142	0.768	0.359	58.3	0.807	0.19	1534		3.2	11.2	
AL085	6/1/94	191	0.611	BIDL	59.2	0.761	0.13	1547	9109	3.7	10.5	7.7
AL085	6/16/94	262	0.577	BIDL	59.5	0.883	0.13	1414	8979	3.3	10.1	7.1
AL085	7/1/94	247	0.583	BIDL	69.5	0.900	0.14	1158	9050	3.0	17.3	
AL085	7/14/94	136	0.612	BIDL	72.1	0.601	0.17	1528	9201	2.9	17.0	
AL085 2nd	7/14/94	87.7	0.633	BIDL	72.8	0.541	0.16	1572	8990	3.0		
AL085	7/28/94	111	0.606	0.110	70.7	0.676	0.15	1509	9764	2.8	18.1	
AL085	9/19/94	86.4	0.721	0.209	84.5	0.691	0.24	1632	9929	2.8	15.3	
AL125	5/23/94	26.0	0.035	BIDL	49.2	0.182	0.05	89.2	416	2.9		
AL125	5/27/94	31.9	BIDL	BIDL	34.5	0.135	BIDL	42.7	432	3.0	9.4	8.0
AL125 2nd	5/27/94	32.8	BIDL	BIDL	35.3	0.144	BIDL	42.0	407	3.0	8.7	
AL125	6/1/94	30.1	BIDL	BIDL	38.8	0.137	BIDL	41.9	864	3.3	9.2	8.3
AL125	6/16/94	31.3	BIDL	BIDL	41.4	0.148	BIDL	42.8	426	2.9	9.7	3.2
AL125	7/1/94	31.1	BIDL	BIDL	43.2	0.149	BIDL	36.6	437	3.0	15.0	
AL125 FD	7/1/94	31.3	BIDL	BIDL	44.3	0.148	BIDL	36.1	427			
AL125	7/14/94	33.9	BIDL	BIDL	52.3	0.166	BIDL	45.9	510	2.7	15.2	
AL125 2nd	7/14/94	36.4	0.024	BIDL	57.5	0.215	BIDL	59.3	610	2.7		
AL125	7/28/94	32.1	BIDL	BIDL	54.6	0.215	BIDL	62.0	681	2.7	16.7	
AL125	9/19/94	31.0	BIDL	BIDL	60.3	0.225	0.03	75.9	753	2.8	15.1	
A10	7/28/94	84.0	BIDL	BIDL	27.9	0.702	0.02	25.2	810	5.7		
B10 2.7'	7/28/94	25.3	BIDL	BIDL	10.1	0.175	BIDL	0.783	111	6.1	20.6	
B10 4.7'	7/28/94	25.0	BIDL	BIDL	9.56	0.201	BIDL	1.03		6.5	18.6	
B10 7.5'	7/28/94	28.0	0.073	BIDL	27.7	0.258	0.04	15.7	465	5.0	13.5	0.3
B40	5/27/94	65.5	0.053	BIDL	37.1	0.267	BIDL	13.9	737	4.3	9.3	0.6
B50 6.25'	5/27/94	80.3	0.057	BIDL	18.5	0.589	BIDL	26.7	737	4.7	7.3	1.0
BL032	6/1/94	67.2	0.514	BIDL	48.6	0.934	0.05	1058	5660	4.3	13.5	
BL032	6/16/94	70.4	0.464	BIDL	44.8	1.015	0.05	845	5258	3.8	9.8	
BL032	7/1/94	147	0.400	BIDL	44.1	1.197	0.04	657	4934	3.8	18.4	
BL032	7/14/94	142	0.459	BIDL	48.4	1.056	0.05	877	5499	3.7	19.8	

		WATER CHEMISTRY - Miles Crossing -Silver Bow Crk. Research Site - Summer 1994. Concentrations in mg/L. See "key to sample names" for explanation of sample names.									
Instrument detect. limit		*0.06*	*0.06*	*0.15*	*0.009*	*0.009*	*0.04*	*0.04*	*0.09*	*0.02*	*0.016*
Samp name	Date	Al	As	Ca	Cd	Co	Cu	Fe	Mg	Mn	Mo
BL032 2nd	7/14/94	107	0.081	496	2.84	0.480	867	0.85	85.1	491	0.025
BL032	7/28/94	135	BIDL	482	3.00	0.554	984	0.52	97.0	531	0.019
BL055	5/23/94	479	BIDL	401	3.68	0.742	1117	2.16	154	404	0.020
BL055	5/27/94	311	BIDL	466	3.15	0.643	853	1.78	131	316	0.033
BL055	6/1/94	254	BIDL	493	2.59	0.495	710	1.41	108	280	BIDL
BL055	6/16/94	216	BIDL	416	2.46	0.464	611	1.36	101	224	BIDL
BL055	7/1/94	243	BIDL	457	2.57	0.487	701	1.53	106	287	BIDL
BL055	7/14/94	293	0.13	502	2.81	0.520	788	1.78	113	288	0.019
BL055 2nd	7/14/94	316	0.33	512	2.83	0.530	808	2.19	109	296	BIDL
BL055	7/28/94	313	BIDL	508	2.65	0.525	868	1.92	111	311	BIDL
BL055	9/19/94	361	BIDL	491	3.41	0.705	876	3.09	129	326	BIDL
BL087	5/27/94	614	11	325	4.00	0.616	424	1230	158	263	1.76
BL087	6/1/94	658	15	470	4.57	0.646	462	1480	201	302	1.57
BL087	7/14/94	1320	41	546	9.46	1.17	831	2950	384	520	4.07
BL087 2nd	7/14/94	1300	40	532	9.14	1.14	816	2900	377	502	4.00
BL087	7/28/94	1470	47	567	8.47	1.26	794	3630	389	470	5.15
BL114	5/23/94	222	0.15	325	1.71	0.324	139	446	85.1	117	0.632
BL114	5/27/94	84	BIDL	180	0.832	0.150	66.0	187	44.1	57.5	0.270
BL114	6/1/94	63	0.080	157	0.684	0.117	50.7	142	39.6	47.6	0.198
BL114	6/16/94	62	0.094	159	0.678	0.116	51.3	138	40.6	47.6	0.191
BL114	7/1/94	68	0.095	154	0.709	0.123	55.9	149	43.0	50.9	0.196
BL114	7/14/94	80	0.33	174	0.810	0.135	64.6	169	47.3	53.8	0.235
BL114 2nd	7/14/94	105	0.70	195	0.979	0.168	78.3	251	54.0	62.0	0.348
BL114	7/28/94	97	0.18	211	0.926	0.167	74.2	235	52.5	64.3	0.305
BL114	9/19/94	98	0.25	216	1.01	0.182	74.4	223	54.9	67.2	0.320
BL130	5/27/94	16	BIDL	113	0.214	0.033	18.4	15.5	29.2	32.8	0.023
BL130	6/1/94	18	BIDL	121	0.215	0.034	15.1	15.8	30.5	29.9	0.026
BL130	6/16/94	17	BIDL	123	0.210	0.034	15.2	126	33.2	39.8	0.175
BL130	7/1/94	15	BIDL	119	0.199	0.029	14.2	55.1	31.6	32.8	0.077
BL130	7/14/94	16	BIDL	129	0.229	0.032	11.7	47.2	34.0	31.6	0.067
BL130 2nd	7/14/94	15	BIDL	129	0.243	0.025	11.4	43.9	33.6	30.6	0.065
BL130	7/28/94	18	BIDL	134	0.247	0.035	12.3	32.6	36.1	32.9	0.048
BL130	9/19/94	16	BIDL	137	0.271	0.037	11.2	21.6	34.8	31.1	0.032
P01	5/27/94	BIDL	BIDL	50.6	BIDL	BIDL	0.258	BIDL	12.0	4.25	BIDL
P01	6/1/94	BIDL	BIDL	53.5	0.010	BIDL	0.287	BIDL	12.1	3.59	BIDL
P01	6/16/94	BIDL	BIDL	51.4	0.011	BIDL	0.221	0.06	11.5	3.60	BIDL
P01	7/1/94	BIDL	BIDL	47.0	0.010	BIDL	0.546	BIDL	11.0	3.70	BIDL
P01	7/14/94	BIDL	BIDL	55.2	0.009	BIDL	0.292	BIDL	12.0	4.11	BIDL
P01	7/28/94	BIDL	BIDL	55.9	0.012	BIDL	0.334	0.05	13.0	4.63	BIDL
P01	9/19/94	BIDL	BIDL	52.6	0.009	BIDL	0.340	0.13	12.8	5.73	BIDL
P01B	5/27/94	0.26	BIDL	56.2	0.023	BIDL	2.35	0.27	12.7	2.57	BIDL
P01B	6/1/94	0.10	BIDL	51.0	0.018	BIDL	0.873	0.18	11.3	2.38	BIDL

		WATER CHEMISTRY - Miles Crossing -Silver Bow Crk. Research Site - Summer 1994. Concentrations in mg/L. See "key to sample names" for explanation of sample names.										
Instrument detect. limit		*0.35*	*0.023*	*0.095*	*0.09*	*0.008*	*0.02*	*0.095*				
Samp name	Date	Na	Ni	Pb	Si	Sr	Ti	Zn	SO_4	pH	T (C)	dO_2
BL032 2nd	7/14/94	104	0.462	BIDL	48.1	0.973	0.05	925		3.8	20.5	
BL032	7/28/94	67.9	0.513	BIDL	54.9	0.975	0.07	1001	569	3.6	17.6	
BL055	5/23/94	351	0.749	BIDL	51.9	1.317	0.07	1023	6983	3.8		
BL055	5/27/94	337	0.689	BIDL	51.7	2.052	0.09	835		3.8	11.3	5.7
BL055	6/1/94	293	0.490	BIDL	51.9	2.028	0.05	755		4.2	12.4	
BL055	6/16/94	263	0.465	BIDL	51.7	1.816	0.04	556	5665	3.8	10.2	
BL055	7/1/94	315	0.490	BIDL	57.5	1.838	0.05	606	6117	3.6	19.7	
BL055	7/14/94	304	0.536	BIDL	64.8	1.630	0.05	789	6136	?	20.4	
BL055 2nd	7/14/94	299	0.560	BIDL	63.9	1.495	0.06	816		3.5		
BL055	7/28/94	272	0.523	BIDL	64.5	1.542	0.06	829	695	3.5	18.2	
BL055	9/19/94	197	0.681	BIDL	79.1	1.058	0.09	875	7365	3.4	16.8	
BL087	5/27/94	989	0.646	0.869	66.0	1.857	0.95	1022		3.0	9.8	6.9
BL087	6/1/94	1160	0.576	0.610	66.9	2.507	0.89	1219	14080	3.1	11.9	
BL087	7/14/94	388	1.10	0.720	129	1.114	1.20	2470	21823	2.2	23.6	
BL087 2nd	7/14/94	335	1.08	0.750	129	0.925	0.93	2429	22941	2.2	18.0	
BL087	7/28/94	96.6	1.09	1.140	154	0.323	1.28	2371		2.1		
BL114	5/23/94	227	0.302	0.127	105	1.080	0.07	234	5605	2.7		
BL114	5/27/94	113	0.156	BIDL	62.6	0.693	0.03	121	2590	2.7	8.7	5.7
BL114	6/1/94	92.5	0.118	BIDL	58.5	0.601	BIDL	101	1872	3.1	10.2	
BL114	6/16/94	95.4	0.114	BIDL	59.4	0.624	BIDL	100	1896	2.7	9.0	2.4
BL114	7/1/94	99.5	0.117	BIDL	66.4	0.679	BIDL	111	2149	2.5	15.0	
BL114	7/14/94	116	0.140	BIDL	70.5	0.683	BIDL	127	2241	2.7	14.9	
BL114 2nd	7/14/94	144	0.173	BIDL	74.0	0.671	0.02	154	2400	2.5	13.2	
BL114	7/28/94	122	0.159	BIDL	69.8	0.767	0.02	165	2622	2.5	15.0	
BL114	9/19/94	111	0.169	BIDL	78.5	0.716	0.04	165	2812	2.3	13.0	
BL130	5/27/94	84.3	0.048	0.124	34.0	0.672	0.03	42.7	794	3.4	7.9	1.5
BL130	6/1/94	79.6	0.055	0.161	36.1	0.592	0.04	41.2		3.7	8.4	
BL130	6/16/94	88.3	0.059	0.112	41.1	0.662	0.03	43.9	858	3.2	7.8	1.7
BL130	7/1/94	84.4	0.043	BIDL	40.3	0.615	0.05	41.8	857	3.0	10.8	
BL130	7/14/94	90.2	0.054	BIDL	40.1	0.608	0.06	41.0	966	3.0	13.7	
BL130 2nd	7/14/94	81.5	0.047	BIDL	41.7	0.592	0.06	41.7	972	3.1	11.2	
BL130	7/28/94	87.6	0.053	BIDL	45.3	0.685	0.08	43.6	1029	2.9	12.1	
BL130	9/19/94	75.8	0.049	0.109	41.8	0.597	0.07	44.7	1132	2.8	11.8	
P01	5/27/94	26.4	BIDL	BIDL	10.8	0.275	BIDL	2.81	108	6.9	6.9	1.4
P01	6/1/94	26.2	BIDL	BIDL	12.0	0.260	BIDL	2.66	101	7.3	7.7	1.6
P01	6/16/94	25.1	BIDL	BIDL	12.3	0.248	BIDL	2.60	110	6.7	7.1	0.4
P01	7/1/94	28.1	BIDL	BIDL	13.8	0.244	BIDL	2.64	98.9	6.9	11.7	
P01	7/14/94	27.6	BIDL	BIDL	14.3	0.264	BIDL	2.93	130	6.8	13.9	
P01	7/28/94	28.5	BIDL	BIDL	15.5	0.299	BIDL	3.31	133	6.6	12.2	
P01	9/19/94	31.7	BIDL	BIDL	12.8	0.288	BIDL	2.47	108	6.6	13.9	
P01B	5/27/94	25.8	BIDL	BIDL	9.13	0.257	BIDL	6.46	172	6.0	7.5	1.5
P01B	6/1/94	24.6	BIDL	BIDL	9.41	0.209	BIDL	4.75	140	6.3	8.1	1.7

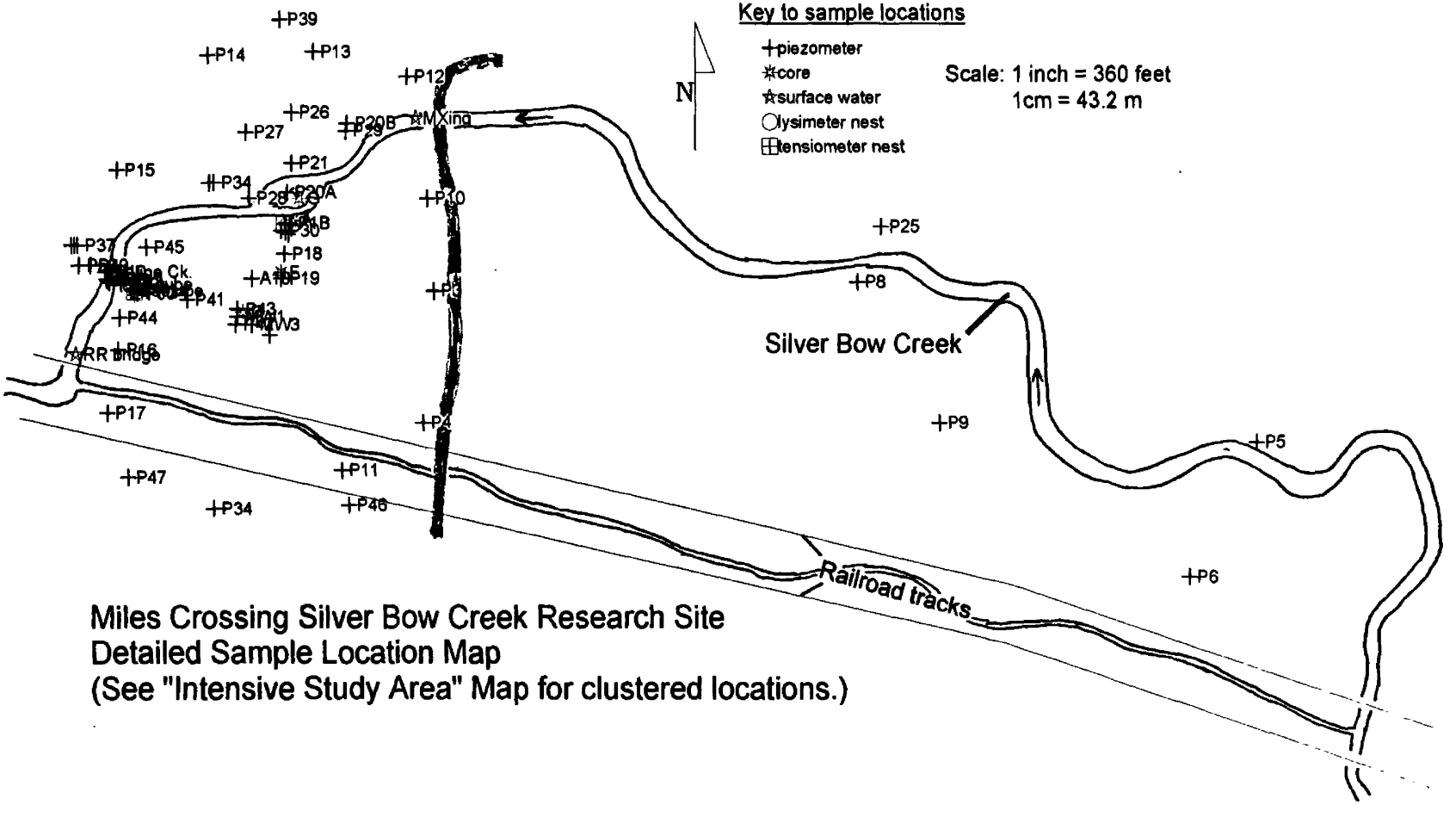
		WATER CHEMISTRY - Miles Crossing -Silver Bow Crk. Research Site - Summer 1994. Concentrations in mg/L. See "key to sample names" for explanation of sample names.									
Instrument detect. limit		*0.06*	*0.06*	*0.15*	*0.009*	*0.009*	*0.04*	*0.04*	*0.09*	*0.02*	*0.016*
Samp name	Date	Al	As	Ca	Cd	Co	Cu	Fe	Mg	Mn	Mo
P01B	6/16/94	0.32	BIDL	50.1	BIDL	BIDL	0.352	0.94	11.5	0.97	BIDL
P01B	7/1/94	BIDL	BIDL	45.1	0.010	BIDL	0.379	BIDL	10.1	2.20	BIDL
P01B	7/14/94	BIDL	BIDL	47.7	BIDL	BIDL	0.177	BIDL	10.0	0.65	BIDL
P01B	7/28/94	BIDL	BIDL	65.8	0.012	BIDL	0.236	0.07	15.1	1.19	BIDL
P01B	9/19/94	BIDL	BIDL	59.9	0.014	BIDL	0.309	BIDL	13.1	0.85	BIDL
P03	5/27/94	0.45	BIDL	180	0.092	0.041	BIDL	0.05	57.1	48.6	BIDL
P04	5/27/94	2.4	BIDL	278	0.306	0.072	16.7	29.1	74.2	57.3	0.048
P06	6/16/94	BIDL	BIDL	96.4	BIDL	BIDL	BIDL	21.9	23.9	10.9	0.036
P08	6/16/94	2.6	BIDL	39.7	0.052	0.019	4.70	19.9	8.98	4.86	0.029
P09	6/16/94	1.8	BIDL	71.0	0.081	0.046	1.94	0.10	24.7	16.3	BIDL
P10	5/27/94	BIDL	BIDL	231	BIDL	0.037	BIDL	10.2	54.3	23.2	0.018
P12	6/1/94	BIDL	BIDL	288	BIDL	BIDL	BIDL	18.2	74.7	18.5	0.026
P13	6/1/94	BIDL	BIDL	161	0.038	0.017	0.193	2.55	41.5	13.4	BIDL
P14	6/1/94	BIDL	BIDL	104	BIDL	0.010	BIDL	6.05	25.8	10.6	0.022
P15	6/1/94	BIDL	BIDL	114	BIDL	BIDL	BIDL	11.1	26.1	2.71	0.024
P16	5/27/94	16	BIDL	254	0.458	0.141	32.8	33.6	72.9	83.3	0.061
P17	6/16/94	BIDL	BIDL	120	BIDL	0.012	BIDL	40.4	27.7	11.2	0.063
P18	5/27/94	BIDL	BIDL	179	BIDL	BIDL	BIDL	12.6	47.2	11.9	0.022
P18	7/28/94	BIDL	BIDL	194	BIDL	BIDL	BIDL	11.3	52.2	13.1	0.022
P19	5/27/94	BIDL	BIDL	179	BIDL	BIDL	BIDL	15.6	47.9	26.9	0.025
P19	7/28/94	BIDL	BIDL	191	BIDL	BIDL	BIDL	8.30	53.8	29.4	BIDL
P20A	7/28/94	BIDL	BIDL	61.1	BIDL	BIDL	0.043	0.26	13.5	1.87	BIDL
P20B	6/1/94	BIDL	BIDL	46.7	BIDL	BIDL	BIDL	2.01	9.16	1.02	0.021
P21	6/1/94	1	BIDL	78.2	0.070	0.039	4.48	7.34	16.1	5.38	BIDL
P22	5/27/94	19	BIDL	57.8	0.085	0.057	11.9	171	16.4	13.0	0.241
P22	7/28/94	34	BIDL	112	0.115	0.087	15.6	247	33.4	24.9	0.329
P22	9/19/94	54	BIDL	113	0.096	0.127	16.4	423	30.5	20.6	0.598
P23	5/27/94	10	BIDL	99.1	0.398	0.070	3.34	105	25.8	19.4	0.147
P23	6/1/94	10	BIDL	100	0.378	0.067	3.44	102	26.6	19.2	0.143
P23	6/16/94	10	BIDL	95.6	0.208	0.054	5.05	81.5	27.3	19.1	0.115
P23	7/1/94	8	BIDL	94.2	0.196	0.049	18.7	62.7	27.1	19.4	0.085
P23	7/14/94	9	BIDL	94.8	0.281	0.056	3.37	89.3	25.0	18.1	0.124
P23	9/19/94	20	BIDL	128	0.144	0.073	9.38	172	34.8	23.1	0.243
P23	7/28/94	10	BIDL	101	0.163	0.049	4.81	73.5	28.2	20.0	0.107
P24	5/27/94	0.16	0.067	162	BIDL	0.025	0.078	40.2	39.5	23.9	0.064
P25	6/16/94	4.3	BIDL	91.9	0.098	0.038	6.17	0.22	20.1	9.06	BIDL
P26	6/1/94	BIDL	BIDL	87.1	BIDL	0.014	BIDL	18.9	19.3	18.7	0.034
P27	6/1/94	5.8	BIDL	130	0.296	0.084	23.1	34.7	28.8	35.1	0.049
P28	6/1/94	1.2	BIDL	83.7	BIDL	0.027	0.845	33.4	22.5	10.6	0.049
P29	6/1/94	BIDL	0.61	187	BIDL	0.083	BIDL	87.2	44.6	67.5	0.127
P33	6/1/94	BIDL	BIDL	153	BIDL	0.009	BIDL	9.62	35.4	8.70	0.025
P38	6/1/94	BIDL	BIDL	43.0	0.044	BIDL	0.225	0.20	9.83	1.26	BIDL

		WATER CHEMISTRY - Miles Crossing -Silver Bow Crk. Research Site - Summer 1994. Concentrations in mg/L. See "key to sample names" for explanation of sample names.										
Instrument detect. limit		*0.35*	*0.023*	*0.095*	*0.09*	*0.008*	*0.02*	*0.095*				
Samp name	Date	Na	Ni	Pb	Si	Sr	Ti	Zn	SO_4	pH	T (C)	dO_2
P01B	6/16/94	23.1	BIDL	BIDL	9.06	0.208	BIDL	1.50	120	6.2	7.2	0.8
P01B	7/1/94	24.0	BIDL	BIDL	9.41	0.199	BIDL	2.85	123	6.7	11.5	
P01B	7/14/94	23.8	BIDL	BIDL	9.72	0.197	BIDL	1.60	95.7	6.5	13.0	
P01B	7/28/94	32.3	BIDL	BIDL	11.6	0.301	BIDL	2.53	179	6.7	12.1	
P01B	9/19/94	29.0	BIDL	BIDL	13.5	0.274	BIDL	2.21	132	6.6	14.9	
P03	5/27/94	121	0.182	BIDL	33.6	1.186	BIDL	49.8		6.1	8.1	0.7
P04	5/27/94	69.8	0.083	BIDL	25.4	1.263	0.03	100		5.4	8.2	2.8
P06	6/16/94	32.7	BIDL	BIDL	23.6	0.538	BIDL	2.54		6.2	8.6	0.4
P08	6/16/94	30.0	BIDL	0.106	11.2	0.154	BIDL	9.44		4.5	8.6	0.5
P09	6/16/94	38.1	0.054	BIDL	38.9	0.523	BIDL	22.2		5.1	8.2	1.4
P10	5/27/94	120	0.039	BIDL	22.4	1.071	0.02	1.38		6.3	8.1	1.1
P12	6/1/94	101	BIDL	BIDL	27.7	1.510	BIDL	0.148		6.9	7.3	
P13	6/1/94	89.1	0.025	BIDL	17.1	0.742	BIDL	7.81		6.8	8.2	
P14	6/1/94	108	BIDL	BIDL	16.7	0.549	BIDL	2.92		7.4	7.0	2.6
P15	6/1/94	76.1	BIDL	BIDL	23.2	0.582	BIDL	BIDL		7.3	6.6	2.0
P16	5/27/94	86.9	0.152	BIDL	43.0	0.957	0.05	116		4.3	7.3	1.8
P17	6/16/94	57.4	BIDL	BIDL	19.6	0.768	BIDL	2.97		6.5	7.9	1.0
P18	5/27/94	96.0	BIDL	BIDL	23.0	0.827	BIDL	BIDL	769	6.7	7.6	3.0
P18	7/28/94	109	BIDL	BIDL	26.2	0.893	BIDL	BIDL		6.6	10.0	0.1
P19	5/27/94	100	BIDL	BIDL	20.8	0.776	BIDL	0.922		6.3	8.1	2.4
P19	7/28/94	112	BIDL	BIDL	20.7	0.874	BIDL	1.56		6.4		
P20A	7/28/94	28.2	BIDL	BIDL	9.41	0.301	BIDL	BIDL	124	6.6	15.2	0.1
P20B	6/1/94	23.5	BIDL	BIDL	7.41	0.170	BIDL	0.606		7.1	8.9	1.4
P21	6/1/94	30.9	0.038	BIDL	18.4	0.341	BIDL	10.7		5.8	9.4	1.9
P22	5/27/94	62.6	0.052	0.136	41.8	0.253	BIDL	14.7	715	4.0	10.1	1.3
P22	7/28/94	74.4	0.077	0.184	57.3	0.454	BIDL	23.9	1277	3.8	17.7	
P22	9/19/94	60.3	0.103	0.237	69.5	0.455	BIDL	22.3	1634	3.7	15.6	
P23	5/27/94	69.7	0.070	BIDL	21.8	0.489	BIDL	23.4	712	4.4	5.8	0.8
P23	6/1/94	71.4	0.073	BIDL	22.5	0.483	BIDL	22.1	715	5.4	9.0	
P23	6/16/94	78.2	0.059	BIDL	22.8	0.457	BIDL	18.0	677	4.5	5.2	1.4
P23	7/1/94	78.5	0.058	BIDL	23.4	0.462	BIDL	19.7	680	4.4	8.6	
P23	7/14/94	73.3	0.063	BIDL	23.6	0.437	BIDL	20.6	670	4.4	8.6	0.4
P23	9/19/94	74.0	0.064	BIDL	46.3	0.600	BIDL	21.3	1058	4.0		
P23	7/28/94	74.1	0.054	BIDL	25.3	0.459	BIDL	19.2	808	4.3	8.7	
P24	5/27/94	81.4	BIDL	BIDL	15.9	0.708	BIDL	9.18		6.2	7.0	1.3
P25	6/16/94	43.0	0.054	BIDL	33.6	0.450	BIDL	16.4		4.6	7.3	2.5
P26	6/1/94	45.9	BIDL	BIDL	12.8	0.301	BIDL	3.94		6.8	9.6	1.4
P27	6/1/94	51.9	0.091	BIDL	40.5	0.777	BIDL	96.1		4.9	9.9	
P28	6/1/94	62.6	BIDL	BIDL	16.6	0.408	BIDL	7.86		5.3	8.8	1.1
P29	6/1/94	97.0	0.064	BIDL	18.7	0.521	BIDL	43.4		6.6	12.0	0.9
P33	6/1/94	89.2	BIDL	BIDL	14.3	0.864	BIDL	0.430		7.6	6.4	1.4
P38	6/1/94	28.4	BIDL	BIDL	11.0	0.197	BIDL	0.804		7.1	11.3	0.9

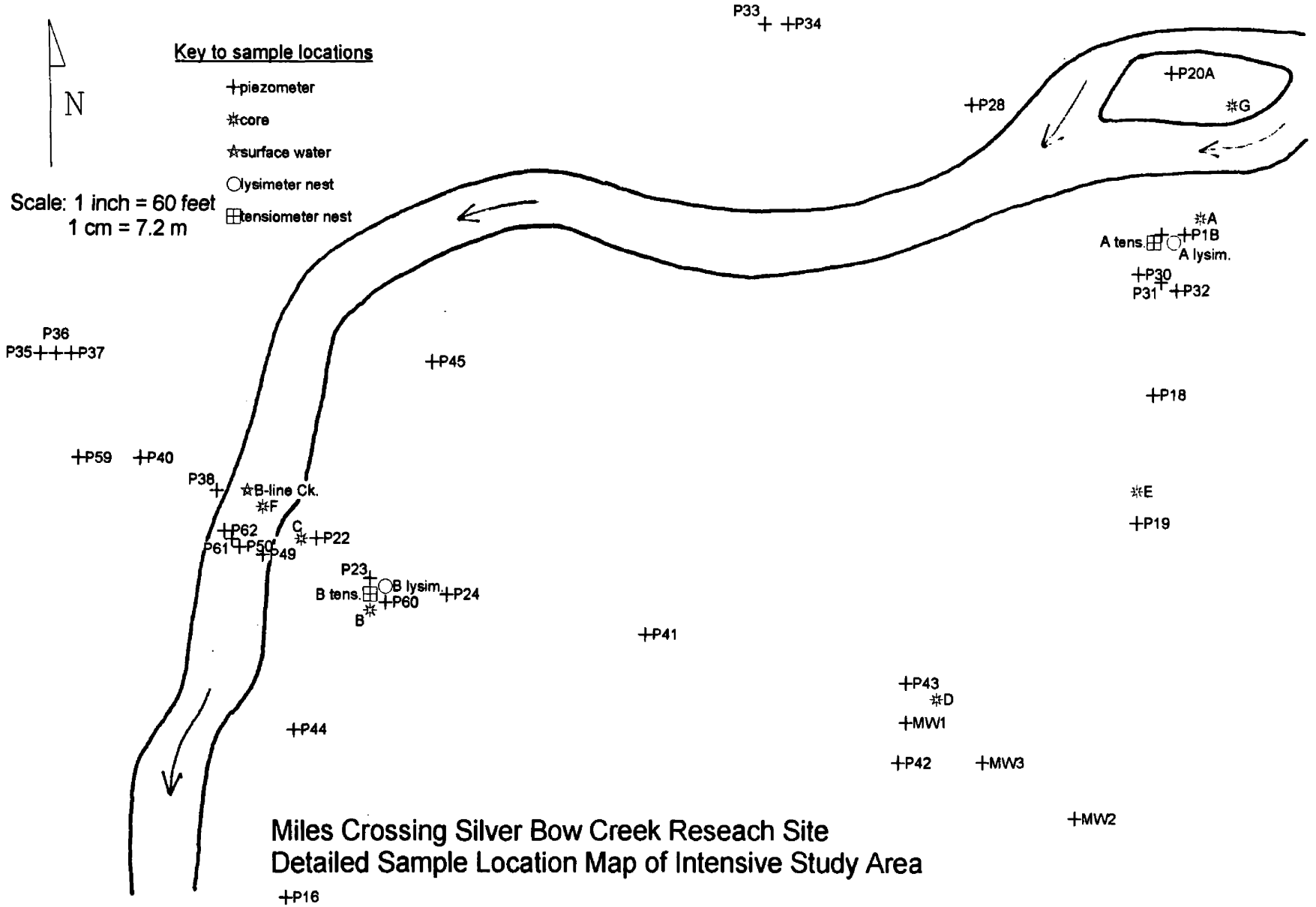
		WATER CHEMISTRY - Miles Crossing -Silver Bow Crk. Research Site - Summer 1994. Concentrations in mg/L. See "key to sample names" for explanation of sample names.									
Instrument detect. limit		*0.06*	*0.06*	*0.15*	*0.009*	*0.009*	*0.04*	*0.04*	*0.09*	*0.02*	*0.016*
Samp name	Date	Al	As	Ca	Cd	Co	Cu	Fe	Mg	Mn	Mo
P38	7/28/94	BIDL	BIDL	44.1	0.035	BIDL	0.192	0.09	10.2	1.39	BIDL
P39	6/1/94	BIDL	BIDL	66.5	BIDL	BIDL	0.042	BIDL	19.3	6.08	0.019
P40	6/1/94	6.9	BIDL	216	0.013	0.313	BIDL	413	42.6	30.4	0.567
P41	5/27/94	BIDL	BIDL	211	BIDL	BIDL	BIDL	31.3	56.5	38.0	0.051
P42	5/27/94	0.090	0.064	384	BIDL	0.014	BIDL	51.8	89.1	38.3	0.087
P42	7/28/94	BIDL	BIDL	350	BIDL	BIDL	BIDL	46.4	86.4	36.3	0.079
P43	7/28/94	0.75	BIDL	173	BIDL	BIDL	BIDL	18.7	47.1	26.7	0.036
P44	5/27/94	13	BIDL	183	0.172	0.064	12.4	67.3	45.9	38.1	0.098
P46	6/16/94	BIDL	0.060	64.4	BIDL	BIDL	BIDL	0.89	10.8	0.65	BIDL
P47	6/16/94	BIDL	0.075	71.0	BIDL	BIDL	BIDL	BIDL	9.78	0.06	BIDL
P49	7/28/94	6.1	0.24	60.7	0.153	0.071	10.7	141	13.2	12.5	0.204
P50	7/28/94	BIDL	BIDL	48.1	0.020	BIDL	0.210	0.12	7.18	2.83	BIDL
P60	5/27/94	2.9	BIDL	165	0.085	0.024	2.21	29.0	42.5	27.4	0.041
P60	6/1/94	2.2	BIDL	174	0.081	0.027	1.20	30.9	44.5	26.8	0.050
P60	6/16/94	1.3	BIDL	140	0.053	0.020	0.206	28.7	36.3	20.8	0.041
P60	7/1/94	3.1	BIDL	143	0.072	0.026	6.67	7.62	36.9	24.5	BIDL
P60	7/14/94	1.3	BIDL	142	0.085	0.029	0.101	35.1	35.6	23.7	0.049
P60	7/28/94	1.3	BIDL	131	0.084	0.033	0.148	31.6	33.3	23.5	0.046
P60	9/19/94	2.7	BIDL	116	0.424	0.048	0.315	55.2	29.5	24.3	0.080
P61	7/28/94	0.62	0.064	48.4	0.076	0.042	0.096	86.3	10.1	7.41	0.127
P62	7/28/94	1.2	BIDL	51.7	BIDL	BIDL	2.62	2.94	11.0	0.11	BIDL
M.Xing	5/23/94	BIDL	BIDL	42.0	BIDL	BIDL	0.071	0.04	9.30	0.63	BIDL
M.Xing	6/16/94	0.06	BIDL	41.6	BIDL	BIDL	0.161	0.16	8.51	0.74	BIDL
RRBrdg	5/23/94	BIDL	BIDL	44.7	BIDL	BIDL	0.064	0.11	9.89	0.68	BIDL
B-line Ck	6/1/94	BIDL	BIDL	50.6	BIDL	BIDL	0.068	0.05	11.0	0.81	BIDL
B-line Ck	7/1/94	BIDL	BIDL	44.7	BIDL	BIDL	0.096	0.04	9.76	0.38	BIDL
B-line Ck	7/14/94	BIDL	BIDL	54.7	BIDL	BIDL	0.056	0.05	11.4	0.94	BIDL
B-line Ck	7/28/94	BIDL	BIDL	50.6	BIDL	BIDL	0.054	BIDL	11.4	0.63	BIDL

		WATER CHEMISTRY - Miles Crossing -Silver Bow Crk. Research Site - Summer 1994. Concentrations in mg/L. See "key to sample names" for explanation of sample names.										
Instrument detect. limit		*0.35*	*0.023*	*0.095*	*0.09*	*0.008*	*0.02*	*0.095*				
Samp name	Date	Na	Ni	Pb	Si	Sr	Ti	Zn	SO_4	pH	T (C)	dO_2
P38	7/28/94	27.0	BIDL	BIDL	11.2	0.206	BIDL	0.925		6.7	17.6	0.3
P39	6/1/94	148	BIDL	BIDL	14.1	0.395	BIDL	1.54		7.7	7.2	3.6
P40	6/1/94	39.8	0.220	BIDL	21.5	1.033	BIDL	78.5		5.4	6.8	
P41	5/27/94	107	BIDL	BIDL	27.6	1.149	BIDL	7.46		6.6	6.6	1.4
P42	5/27/94	118	BIDL	BIDL	18.3	1.621	0.04	2.13		6.5	6.2	1.1
P42	7/28/94	128	BIDL	BIDL	22.4	1.612	BIDL	2.02	1455	6.5	8.6	0.2
P43	7/28/94	88.8	BIDL	BIDL	32.3	0.808	0.05	3.08	724	6.4	9.4	0.5
P44	5/27/94	90.8	0.064	0.229	31.4	0.788	0.02	39.8		4.3	7.1	1.6
P46	6/16/94	26.4	BIDL	BIDL	13.6	0.340	BIDL	0.678		6.8	10.4	7.0
P47	6/16/94	39.7	BIDL	BIDL	17.8	0.304	BIDL	BIDL		7.2	8.2	
P49	7/28/94	30.9	0.062	0.467	32.2	0.252	0.05	17.1	530	4.7	14.0	0.1
P50	7/28/94	14.8	BIDL	BIDL	6.11	0.177	BIDL	1.48	118	6.3		
P60	5/27/94	83.0	BIDL	BIDL	19.9	0.745	BIDL	16.6	783	5.1	6.1	0.4
P60	6/1/94	87.1	0.025	BIDL	20.9	0.764	BIDL	13.9	1431	5.4	9.0	1.2
P60	6/16/94	80.8	BIDL	BIDL	18.7	0.637	BIDL	10.5	651	5.4	6.9	1.2
P60	7/1/94	87.2	BIDL	BIDL	20.2	0.671	BIDL	15.2	734	5.2	10.8	
P60	7/14/94	87.0	0.026	BIDL	21.7	0.628	BIDL	17.4	702	5.6	11.9	0.9
P60	7/28/94	75.2	0.033	BIDL	19.8	0.570	0.02	18.9	697	5.5	11.2	
P60	9/19/94	79.1	0.057	BIDL	25.4	0.546	BIDL	30.0	660	5.1	10.8	
P61	7/28/94	28.5	0.056	BIDL	23.8	0.200	0.03	16.9	357	4.9	16.3	
P62	7/28/94	22.1	BIDL	BIDL	10.2	0.231	0.04	0.384	87.7	6.9	17.6	0.1
M.Xing	5/23/94	22.3	BIDL	BIDL	12.2	0.228	BIDL	0.293	65.8	7.7	17.0	
M.Xing	6/16/94	21.3	BIDL	BIDL	11.1	0.198	BIDL	0.436	62.1	8.0	13.0	9.4
RRBrdg	5/23/94	23.6	BIDL	BIDL	13.0	0.243	BIDL	0.310	66.0	7.8	17.0	
B-line Ck	6/1/94	26.3	BIDL	BIDL	13.3	0.255	BIDL	0.280		8.2	14.2	8.8
B-line Ck	7/1/94	22.6	BIDL	BIDL	9.69	0.204	BIDL	0.148	64.6	8.5	18.7	
B-line Ck	7/14/94	26.3	BIDL	BIDL	11.3	0.247	BIDL	0.384	88.2	8.1	17.7	
B-line Ck	7/28/94	26.3	BIDL	BIDL	11.5	0.245	BIDL	0.365	83.5	8.0	18.3	

Appendix of Photographs and Detailed Site Maps



Miles Crossing Silver Bow Creek Research Site
Detailed Sample Location Map
(See "Intensive Study Area" Map for clustered locations.)



Miles Crossing Silver Bow Creek Reseach Site
Detailed Sample Location Map of Intensive Study Area

Photo 1. (Top) Close-up of yellow globular efflorescent surface crust found in late summer on low bench 30 cm above creek.

Photo 2. (Bottom) Coring procedure. A Handyman jack is used to pound plastic tube into the floodplain. Looking north at location of Core C.

Photo 3. Efflorescent surface crusts formed by evaporation of metal and sulfate rich vadose zone water.

Photo 4. Bank of Silver Bow Creek showing the heterogeneous floodplain stratigraphy and highly oxidized vadose sedimetns. Instrumentation in photo is Site A. Looking southeast.

Photo 5. Overview of the Miles Crossing Study Site. Silver Bow Creek runs through the contaminated floodplain. I am standing at Site B. Looking northeast.